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OTANICAL MEMOIRS. No. 15

INTRODUCTION TO THE PLANT-LIFE OF THE OXFORD DISTRICT

III. THE ANNUAL SUCCESSION. (July—December)

By

A. H. CHURCH, M.A.

HUMPHREY MILFORD
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NEW YORK TORONTO MELBOURNE CAPE TOWN
BOMBAY CALCUTTA MADRAS SHANGHAI

1925

Price Three Shillings and Sixpence net

1. 'Matthew Arnold's Tree', Pickett's Heath; Sept. 3, 1922.

2. Oxford from Seven-fields Footpath, South Hinksey; Wheat in shock (var. Yeoman); Aug. 7, 1923.

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VI. MIDSUMMER

No other happening of the countryside marks more definitely the turn of the year than the Hay Harvest; more especially as it is so closely associated with the Summer solstice, being normally at an optimum in the fourth week of June. This week also includes the conventional Midsummer Day (June 24); and allowing for the change of the Calendar which makes Old Midsummer Day fall well within the hot days at the end of the first week of July,[1] it is convenient to regard the weeks from the longest day to the middle of July as covering the full Midsummer period.

From the end of June a distinct change comes over the flora, and with the carrying of the hay-crop the forms scheduled for early summer begin to fruit out and disappear. Though many may continue to follow on in diminished quantity, and others only reach their optimum later, the approach of new conditions begins to make itself felt. This becomes more obvious in a district in which the original woodland has been largely denuded, and grass-land is now predominant;[2] and though the fields are increasingly bare, as the hay is cut before many of the included forms had fully matured seed, this period marks the culmination of the plant-year.

> At this time the Nightingale ceases to sing, the Cuckoo gives up calling, young birds are fledged and grown, summer butterflies appear, and the season is so far over in that there is little that is new to come on. The summer growth is completed; it only remains to see how long it can carry on. Henceforward light is failing, and though only slowly at first and hardly noticed, the decline is none the less sure; and with this the flowers begin to fall off in variety as well as in luxuriance. The apex of the curve of plant-growth is thus obviously that of the curve of duration of sunlight.
>
> The most striking feature is the length of the day, emphasized by the modern institution of 'Summer-time'. On fine evenings at the end of June, Humble-bees work flowers till 9 p.m., and Swifts fly till 10 p.m.; it only grows dusk at 10.30 ('summer-time').

All vegetation is at its best, and there is so far little damage to the new growth. The critical factor is water-supply. Provided the rainfall remains sufficient, the conditions of the culminating period of Midsummer week are continued well into July, as presenting an ideal biological climate for this part of the world, with dazzling sunshine, long days with many hours of sunlight, the weather not too hot, and the sun not sufficiently powerful to become an enemy, the chance of drenching showers, strong drying winds, brilliant cloud-effects of thunder-weather, and the ground kept thoroughly moistened—but also chances of weeks of storm and rain in other years.[3]

Climatic conditions at their summer optimum become less assertive, and are taken for granted. The recorded hours of bright sunshine remain at the same level as in the previous month (total for July averaging 192·1). The cloud-period still accounts for 60% of the total light-period; but the hours of daylight (16½, June 25) only drop to 15¼ at the end of July. The

[1] On June 21 the sun enters the sign Cancer, and marks the Summer solstice; a day's range following the exigencies of a calendar with Leap-years. Old Midsummer Day falls within the 'Dog-days' of July (from July 3), commemorating Sirius the Dog-star.

[2] The amount for the whole county of Oxford is 40%; but there is more in the local area with broad alluvial expanses, and with the encouragement of dairy-farming, pastures tend to increase at the expense of arable land.

[3] A typical Midsummer Day gives continuous sunshine from a blue and perfectly cloudless sky for over 15 hours, a shade-temperature over 80°, with a sun-temperature near 140°, and a night temperature over 60°. In 1921 such weather was characteristic for June 23–5, and also July 6–14; none in 1922; July 11–13, 1923; July 11–12, 1924.

average rainfall ($2\frac{1}{2}$ inches) appears high, but the range for July is from only 0·285 (1921) to an exceptional 5 inches. The effect of a few heavy thunderstorms may pull up the record without affecting the summer heat, or adding much to the supply available for vegetation. The shade-temperature ranges between 70° and 85° by day, falling to 60° in cool spells, and the night temperature rarely falls below 50°.[1] But an occasional heat-wave of short duration may give shade-temperatures over 90° (93·1° July 12, 1923), and sun-exposures rise to 120°–130° and even more (149·5° July 8, 1921).

The characteristic feature of plant-life is the great variety of specific and generic types now at their optimum under optimum conditions; but though the general effect is that of a free-flowering season, there is little special floral display due to the predominance of one or a few special types. Flowering forms become so numerous in the sub-floras, that records are apt to become mere lists; and though woodland, cultivated fields, and watercourses still carry distinctive floras, there is much overlapping in the more commonly accessible formations of hedgerow, roadside, and pasture.

The season presents more particularly the optimum for plants of the *waste*, as seen in woodland-clearings, older neglected road-tracks, and phases of regressive woodland, which become gardens carpeted with minor herbaceous forms. The case of the arable field and the necessary waste of cultivation follows. With the effect of great heat, long hours of sunshine, and drying winds, even the full average rainfall is insufficient to withstand the effects of desiccation. The surface-soil dries and cracks in clay areas; surface-rooting forms are affected, though more deeply-rooted plants may successfully endure. A necessity for xerophytic specialization arises, which is soon reflected in a more xeromorphic type of vegetation, exemplified most clearly in the increasing predominance of Thistles (7 sp.). Otherwise the most typical flowering forms of the period (July 1st week), the special glory of their respective formations, may be taken as—

(1) The Wheat of arable land, now in full bloom, 4 ft. high.
(2) *Rubus fruticosus* (forms), as the flowering Brambles of woodland waste, hedges, and roadsides.[2]
(3) *Nymphaea alba*, as the White Waterlily of streams and ponds.[3]
(4) *Lilium candidum*, the Madonna Lily of the gardens, a bulbous form of the Mediterranean district.[4]

The early July flora includes some 300 species possibly available in blossom, and adds some 130 forms to the June list. There is so far little lost beyond the earliest Spring flowers; strays still occur of many May flowers in shady situations, inconspicuous and lost in rank overgrowth. Residual grasses flower out along roadsides and in woodland clearings. Arable weeds coming up with spring-sown Barley extend the flowering period of forms otherwise flowering out in June among the winter-sown Wheat.

In woodland the canopy shows a dull green, and is at its densest; few leaves are as yet exhausted and shed;[5] even damaged Oaks are recovering from the ravages of the first brood of the Tortrix Moth caterpillars, and the

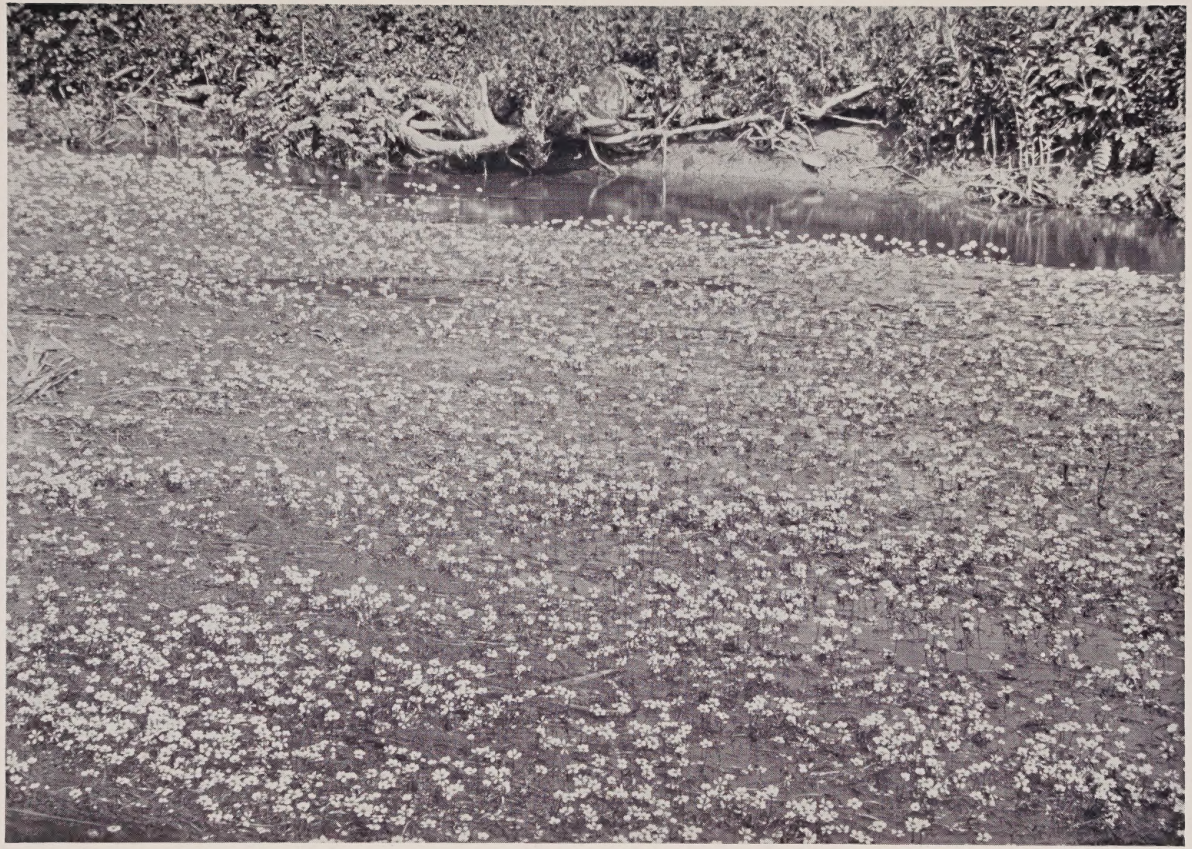
[1] July 1, 1924, just touched a white frost at 3.30 a.m.; three degrees of frost outside the town.

[2] More particularly the fine form *leucostachys*, abundant in clay areas, the larger bushes to 10 ft., bearing close-set panicles of pale pinkish blossom, and stout spinous violet-purple stems.

[3] A northern stray of an essentially tropical family, flourishing in warm quiet water, and avoiding frost by perennation below the ice-level. Only found locally in the navigable Thames in the backwater at Pink Hill.

[4] Vegetating in cool winter and spring to flower by May 1 (Greece), to fruit before the dry summer. Very similar in periodicity to the Wheat plant, and in this country similarly delayed two months later in the year.

[5] Heat-shedding of the first yellow leaves is noticed in Willows, and *Daphne Mezereum* of the gardens begins to lose its foliage.



3. *Ranunculus fluitans*; Wolvercote, June 29, 1923.

4. *Epilobium angustifolium*; Bagley, Underwoods, Aug. 4, 1922.

small greenish moths swarm about them. The new season's shoots have reached their full growth; coppice-oak of the first year shows green shoots 3 ft.; Willow shoots are 3 ft., *Clematis Vitalba* runners 6–8 ft.; Brambles and Rose suckers 3–6 ft.[1] All foliage-leaves have attained their maximum dimensions, and the annual shoots have matured their full complement of leaves. Only a few Conifers lag behind with needles and shoots half-grown (*Pinus*, *Cedrus*, *Taxodium*). *Castanea* alone is in full bloom, and this together with the planted Limes of the streets and gardens (as also planted *Liriodendron*) are the only flowering trees of the period. Fruiting stages, green and full size, characterize the majority of trees (*Acer*, *Alnus*, *Betulus*, *Corylus*, *Carpinus*, *Fagus*, *Pinus*), though acorns (5 mm.) are only beginning to grow. Hawthorn and Holly show green berries, though Apples are still small (30 mm.), and Walnuts not half size. The Willows have shed their spent catkins, as also has *Populus nigra*.

Underwood and hedges are still gay with flowering shrubs. Elder and *Cornus* are going over; but Privet is at its optimum, in its turn the most characteristic hedge-shrub of the month. Roses (*R. canina*, *R. arvensis*), Honeysuckle, and Brambles in great variety, add to the display, with *Clematis Vitalba* on calcareous soils. In neglected hedgerows and scrub-thickets, other climbers become characteristic—*Bryonia dioica*, *Tamus communis*, *Solanum Dulcamara*—together with flowering trails of *Calystegia sepium*, and *Humulus Lupulus* (in bud). The Bracken in more open woodland is 6 ft. high, at last only attaining its optimum frond-development as *Aspidium Filix-mas* and *Lastraea dilatata* of damp bottoms are ripening their sporangia. Woodland grasses of delayed growth are more conspicuous (*Poa nemoralis*, *Agropyrum caninum*, *Bromus asper*, *Melica nutans* (fruiting). In the underwood itself flowers are disappearing; *Ajuga* and Sanicle are over; *Mercurialis* fruits are shedding, though Primroses and Violas still maintain their foliage and green capsules. A few residual Orchids persist (*Listera ovata*, *Platanthera chlorantha*, *Orchis maculata*), and a new summer flora includes—

Arctium minus, *Lysimachia Nummularia*, *Circaea Lutetiana*,
Hypericum hirsutum, *Hypericum humifusum*, *Prunella vulgaris*,
Epilobium angustifolium, *Campanula Trachelium*.

In more open clearings grasses are still dominant, many forms becoming spectacular in their optimum flowering stages—

Aira caespitosa, *Agrostis canina*, *Holcus lanatus*,
Dactylis glomerata.

Juncus-forms are also at their optimum (*J. conglomeratus*, *J. glaucus*).

The ground-flora of the clearings, open forest-plots and rides is bright with blossoms of a wide range of residual and intrusive forms—

Potentilla Tormentilla, *Erythraea Centaurium*, (damper tracts)
Fragraria vesca, *Crepis biennis*, *Hypericum quadrangulum*,
Senecio sylvatica, *Galium saxatile*, *Epilobium angustifolium*,
Hypericum pulchrum, *Prunella vulgaris*, *Lotus uliginosus*,
Orchis maculata, *Lysimachia Nummularia*, *Carduus palustris*,
Stachys Betonica, *Galium verum*, *Sagina procumbens*,
Hypericum perforatum, *Epilobium parviflorum*, *Stellaria graminea*,

with abundant larger growths of—

Heracleum Sphondylium, *Pastinaca sativa*, *Carduus lanceolatus*,
Rumex sanguineus, *Senecio Jacobaea*, *Digitalis purpurea*.[2]

[1] Thorn-spray 1½–2 ft., *Prunus spinosa* 1½ ft. and branching to the second degree, as also are Willows; Lammas-shoots of Oak coppice already 1 ft. long.

[2] Foxgloves are conspicuously deficient in the district, though growing luxuriantly in gardens, and where humanly assisted in woodland clearings (Bagley, 1923).

Damp or shaded hedge-bottoms may still show strays of earlier forms (*Lychnis dioica*, *Lamium album*), but the bottom growth fills up with a new summer vegetation—

Galium Mollugo,	*Stachys sylvatica*,	*Geum urbanum*,
Hypericum perforatum,	*Agrimonia Eupatoria*,	*Torilis Anthriscus*,
Pimpinella magna,	*Convolvulus arvensis*,	*Chaerophyllum temulum*,

together with an assemblage of coarse fruiting grasses, flowering *Juncus*-forms, Nettles, Docks (*Rumex conglomeratus*, *R. crispus*, *R. obtusifolius*), Thistles (*Carduus crispus*, *C. lanceolatus*, *C. arvensis*, *C. palustris*), grading to weeds of cultivation and human association—

Plantago major,	*Cichorium Intybus*,	*Bromus sterilis*,
Lapsana communis,	*Conium maculatum*,	*Hordeum murinum*,
Sonchus asper,	*Malva sylvestris*,	*Agropyrum repens*,
Ballota foetida,	*Juncus glaucus*,	*Arrhenatherum avenaceum*.

Much of this rank growth, now at its maximum, is cut and trimmed, either to be utilized by cottagers for fodder and litter, or merely to keep down the weeds, more particularly on railway embankments and along roadsides.[1] Such Midsummer clearing plays an important part in preventing regression of the roadside to the general condition of the neglected hedge, as an incipient scrub-formation of brambles and bushes (*Crataegus*, *Prunus spinosa*, *Cornus sanguinea*), as well as keeping down the larger perennials (*Arctium*, *Artemisia*, *Carduus*, *Heracleum*, *Conium*), and so assisting in giving a tidier and more civilized appearance to the vicinity of human occupation; but it adds to the general bareness of the countryside in the summer season. Incidentally it assists in the distribution of the seeds of the earlier Hedge-forms—

Alliaria officinalis,	*Anthriscus sylvestris*,	*Chaerophyllum temulum*,
Bromus sterilis,	*Galium Aparine*,	*Hordeum murinum*,

and affords an explanation of the ubiquity of these plants in all inhabited districts. After rain a Midsummer crop of seedlings of such early spring types begins to show in every stretch of cleared ground (as also *Poa annua*, *Senecio vulgaris*, *Capsella*, &c.).

On dry banks of calcareous soil, roadsides, and open grassy rides, a close growth of low herbaceous forms flower in the dry turf which may be subject to rough grazing, often with a particularly beautiful effect—

Helianthemum vulgare,	*Lotus corniculatus*,	*Thymus Serpyllum*,
Ononis spinosa,	*Polygala vulgaris*,	*Euphrasia officinalis*,
Galium verum,	*Galium saxatile*,	*Trifolium medium*,
Carlina vulgaris,	*Hieracium Pilosella*,	*Briza media*,
Scabiosa Columbaria,	*Pimpinella Saxifraga*,	*Senecio erucifolius*,
Poterium Sanguisorba,	*Echium vulgare*,	*Potentilla reptans*,

the larger species in dwarfed forms.

Rarely is all the hay carried by June 21 (1921); more usually the Hay-harvest extends well into mid-July (1923–4), following the exigencies of labour-supply and fine weather. A heavy growth of the grass-bottom is more valuable than fruiting panicles; the latter lose seed as they mature, while the stems become wiry, sclerosed, and drained of food-supplies. A thin

[1] Smallholders utilize all such growths of hedge-waste, roadside, and *Juncus*-swamp. The coarse herbage will feed a goat or donkey, and broader tracts may be cut by scythe or hook at this period of optimum growth; all such material being useful for bedding or litter. The sides of railway embankments are cut and largely cleared by fire, and imperfectly equipped farmers may burn growths on banks too steep to use a horse-mower on. The futility of destroying any organic polysaccharide material once synthesized is still little understood, as woodmen still burn large quantities of woodland waste in clearings; but burning is the readiest method of getting rid of thorns, weed-seeds, and fungus-pests.

primary crop may thus be left on the chance that the bottom may fill up with later herbage after rain (particularly *Trifolium repens*), and in unfavourable seasons much cutting may be delayed until August. Only when the crop is cut early in June is there any chance of a second growth by September.[1]

As soon as the hay is cut, the pastures are subject to desiccation, as are also the exposed hedgerows, and their floral display vanishes. Uncut fields also bleach out and their flowers are limited. Only in damp alluvial areas the fields become a vivid green, even when the hay is still lying, and begin a new growth, with recovery of the floral display to a certain extent as aftermath.

The characteristic grasses of the period are—

Trisetum flavescens, *Phleum pratense*, *Agrostis alba*,
Lolium perenne, *Agropyrum repens*, *Agrostis stolonifera*,
Hordeum pratense, *Festuca elatior*, *Glyceria aquatica*.

Residual pastures may still show abundant—

Hypochaeris radicata, *Crepis virens*, *Lathyrus pratensis*,
Centaurea nigra, *Achillea Millefolium*, *Knautia arvensis*,

with the common Clovers; and parasitic on *Trifolium pratense*, as a crop following Oats, often abundant *Orobanche minor* as a casual of cultivation. Damp alluvial meadows left uncut may be coloured over wide stretches with—

Sanguisorba officinalis, *Chrysanthemum Leucanthemum*, *Spiraea Ulmaria*,
Rhinanthus Crista-galli, *Centaurea nigra*,
Hypochaeris radicata, *Silaus pratensis*, *Scabiosa succisa*,
Leontodon autumnalis.

By the second week of July the cornfields are at their optimum growth; the main varieties of wheat are flowering out, beginning to fill their grain, and changing colour in the hot sun. Winter-sown oats are further advanced, and early Barley (6-rowed) and Rye, not cut for green fodder, already golden-yellow. Conspicuous weeds of the corn-crops, usually less in wheat, and more in oats, include—

Lychnis Githago, *Lychnis vespertina*, *Knautia arvensis*,
Papaver Rhoeas, *Chrysanthemum segetum*, *Carduus arvensis*.

Convolvulus arvensis climbing the haulms, and alien grasses as—

Avena fatua, *Bromus secalinus*, *Alopecurus agrestis*.

But *Centaurea Cyanus* is no longer found except as an escape from garden cultivation, and the Darnel (*Lolium temulentum*) has vanished with Fungoid pests as *Tilletia*, *Claviceps*, and *Puccinia graminis*.[2]

Even where the main crop is carefully cleaned, an abundant weed-flora of past seasons is commonly allowed to carry on along the field-margins, foot-paths, and waste-heaps. The last, in particular, in the case of Wheat-fields may present a gorgeous mass of colour (scarlet Poppies, yellow Charlock, white Radish), when the main crop itself is practically unaffected. Such stations also begin to show a wide range of minor perennating forms flowering from seed the first season, as well as more casual annuals now coming into full bloom. These casuals have no fixed tenure, and follow the crops in the cultural rotation: thus flowering as annuals:—

Lithospermum arvense, *Stachys arvensis*, *Trifolium arvense*,
Diplotaxis muralis, (*Sonchus arvensis*), *Matricaria Chamomilla*,
Senebiera Coronopus, *Linaria minor*, *Filago germanica*,
Polygonum Convolvulus, *Lycopsis arvensis*, *Euphorbia Helioscopia*,

[1] Cutting for bedding and litter may take place at any time into November.

[2] *Lolium temulentum* rare about Oxford (Walker, 1833); *Centaurea Cyanus*, general in cornfields (Walker, 1833), has been noted within living memory.

Veronica arvensis, *Anagallis arvensis*, *Euphorbia exigua*,
Sherardia arvensis, *Ranunculus arvensis*, *Papaver dubium*,
Viola Tricolor, *Scandix Pecten-Veneris*, *Polygonum aviculare*,
Linaria spuria, *Linaria Elatine*, *Chenopodium album*;

as perennials with chance of enduring along sides of fields and on waste-heaps—

Convolvulus arvensis, *Melilotus officinalis*, *Medicago sativa*,
Potentilla Anserina, *Lolium italicum*, *Centaurea Scabiosa*.

In all open cleared ground and waste exposed to sun and desiccation, but otherwise neglected and left to the plants which only require such little human assistance to get beyond their fellows, the advance guard of summer xerophytes begins to appear, flourishing so far under optimum conditions. Among these may be included several forms already listed—

Carduus arvensis, *Daucus Carota*, *Senecio Jacobaea*,
Carduus crispus, *Pastinaca sativa*, *Reseda Luteola*,
Carduus lanceolatus, *Achillea Millefolium*, *Helminthia echioides*,
Echium vulgare, *Verbascum Thapsus*, *Centaurea Scabiosa*,

and so far only the first indications of Chenopods and Polygonums—

Chenopodium album, *Polygonum aviculare*, *Polygonum Convolvulus*,
Polygonum Persicaria;

though *Chenopodium Bonus-Henricus* is a familiar escape from cultivation flowering in June.

The finest display of weed-flora is seen in Bean-fields, left untended, which may be a blaze of Poppies, Charlock, and Radish; only in particularly bad cases of neglect are fields coloured with *Chrysanthemum segetum* (yellow), *Matricaria Chamomilla* (white), or *Carduus arvensis* (lilac).

Old stone-walls of the urban area and near habitations give an effective display of—

Sedum acre, *Sedum dasyphyllum*, *Hieracium murorum*,

together with alien escapes—

Antirrhinum majus, *Senecio squalidus*, *Centranthus ruber*,

also occasional *Linaria purpurea* and *Cotyledon umbilicus*.

On the other hand, residual strays of early summer flora linger on in damp corners, with strays of the commoner grasses of the Hay-crop, Daisies, Dandelions—

Plantago lanceolata, *Trifolium minus*, *Lamium album*,
Plantago media, *Trifolium procumbens*,

and the common weeds—

Stellaria media, *Capsella Bursa-pastoris*, *Veronica Tournefortii*,
Lamium amplexicaule, *Aethusa Cynapium*, *Euphorbia Peplus*,

retain a hold on waste-heaps and all allotment areas, mingling with more restricted summer forms of human association, as—

Malva sylvestris, *Solanum nigrum*, *Malva rotundifolium*,

or even *Datura Stramonium*.

The same massed growth of luxuriant vegetation is even more characteristic of aquatic stations; since here water-supply, the variable factor in other formations, is secured. Swamp-grasses, reeds, and *Juncus*-forms attain their maximum growth—

Scirpus lacustris 8–10 ft., *Glyceria aquatica* 8 ft., *Juncus* (sp.) 3 ft., and with them mingle a wide range of herbaceous forms, all now beginning to bloom as they attain their maximum vegetative growth. Sub-aquatics of swamp-woodland extend into ditches and minor water-courses, and are equally characteristic of wet hedge-bottoms—

Ranunculus Flammula, *Spiraea Ulmaria*, *Alopecurus geniculatus*,
Ranunculus Lingua, *Epilobium hirsutum*, *Glyceria plicata*,
Hypericum quadrangulum, *Epilobium tetragonum*.

The main crop of *Glyceria aquatica* runs up its conspicuous wavy panicles in water-courses and along the river-bank (5–7 ft. Glycerietum); Carices are now all in their final fruiting-stages, and open swamp becomes dense Juncetum (3 ft.), with dominant forms—

Juncus glaucus, *Juncus lamprocarpus*, *Juncus effusus*,
Juncus acutiflorus.

In neutral wet-swamp, tending to boggy conditions, though no *Sphagnum*-bog now remains locally, many minor herbaceous forms continue to flourish and these may be emphasized in localities where the larger *Juncus*-forms and associated *Equisetum fluviatile* are periodically cut:—

Anagallis tenella, *Lychnis Flos-cuculi*, *Epipactis palustris*,
Hydrocotyle vulgaris, *Pedicularis palustris*, *Gymnadenia conopsea*,
Galium uliginosum, *Parnassia palustris*, *Orchis incarnata*,

(and also forms not necessarily confined to swampy localities—

Polygala vulgaris, *Briza media*, *Listera ovata*).

These may be distinguished from an equally wide range of sub-aquatics restricted to more ordinary aerated soils and gravels, as expressed in the normal conditions of alluvial meadow and river-bank—

Myosotis palustris, *Veronica Anagallis*, *Galium palustre*,
Scutellaria galericulata, *Veronica Beccabunga*, *Nasturtium sylvestre*,
Achillea Ptarmica, *Stachys palustris*, *Rumex Hydrolapathum*,
Malachium aquaticum, *Apium nodiflorum*, *Ranunculus sceleratus*,
Oenanthe fistulosa, *Valeriana officinalis*, *Lythrum Salicaria*.

These grade into forms more definitely adapted morphologically for the chances of a more permanently aquatic environment. As such may be included:—

(1) The larger rush-growths of the river-bank, with leaves 3–6 ft.—

Sparganium ramosum, *Iris Pseudacorus*, *Acorus Calamus*,
Typha latifolium, *Typha angustifolium*, *Butomus umbellatus*.

(2) Forms with marked differentiation between submerged or floating members and the sub-aerial shoot-systems—

Alisma Plantago, *Sagittaria sagittifolia*, *Scirpus lacustris*,
Oenanthe fluviatilis.[1]

(3) Advanced aquatics trailing at the surface, and flowering little above the water-level—

Nymphaea alba, *Nuphar luteum*, *Potamogeton natans*,
Limnanthemum nymphaeoides.

(4) These again grade into aquatics with vegetative shoots wholly submerged, but flowering at the surface—

Ranunculus fluitans, *Ranunculus circinatus*, *Potamogeton lucens*,
Potamogeton perfoliatus, *Potamogeton flabellatus*, *Potamogeton pectinatus*,

(5) and ultimately flowering wholly submerged—

Potamogeton densus, *Elodea canadensis*, (*Ceratophyllum submersum*.)

[1] This remarkable plant in favourable seasons (1921, 23) rises to flower in massed banks 2 ft. out of the water, or may cover broad expanses of open shallow river (Binsey); the submerged foliage may vegetate at a depth of 3–6 ft. *Sagittaria* floating-leaves now rise to the surface from 2–4 ft. *Alisma* floating-leaves from deep water on 6–10 ft. petioles. *Scirpus lacustris* 6–8 ft. ribbon-leaves lie in the flow of the current or in the direction of the wind. Such submerged forms attain their maximum specialization in clear quiet waters (as in the 'Lake' of the Hinksey Waterworks).

All river-weeds are at a maximum ; and where the water runs clear the bottom is completely hidden by trailing masses of the larger Potamogetons (*P. lucens*, *P. perfoliatus*, *P. pectinatus*, 6 ft. or more,—*P. flabellatus*, 10–12 ft.) ; by surface-trails of *Ranunculus fluitans* (12–15 ft.), the submerged ribbon-leaves of *Scirpus lacustris* (6–8 ft.) and *Sagittaria*.[1]

Flowering Plants (130) to July 25.

(1) Woodland Trees and Shrubs :—

Clematis Vitalba, *Castanea vesca*, (*Tilia vulgaris*.)

(2) Herbaceous Perennials of Woodland and Clearings :—

Teucrium Scorodonia, *Verbascum Thapsus*, *Holcus mollis*,
Rumex sanguineus, *Stachys Betonica*, *Bromus asper*,
Erythraea Centaurium, *Clinopodium vulgare*, *Brachypodium sylvestre*,
Epilobium tetragonum, *Campanula Trachelium*, *Festuca gigantea*,
Juncus conglomeratus, *Arctium minus*, *Hieracium vulgatum*,
Wahlenbergia hederacea, *Arctium majus*, *Serratula tinctoria*,
Gnaphalium sylvaticum, *Arctium intermedium*, *Cynoglossum officinale*,
Lathyrus sylvestris, *Dipsacus sylvestris*, *Galeopsis Tetrahit*.

(3) Hedgerows and Roadsides :—

Rumex conglomeratus, *Calystegia sepium*, *Agropyrum repens*,
Rumex obtusifolius, *Artemisia vulgaris*, *Agropyrum caninum*,
Torilis Anthriscus, *Humulus Lupulus*, *Agrostis alba*,
Sison Amomum, *Helminthia echioides*, *Agrostis stolonifera*,
Ononis arvensis, *Gnaphalium uliginosum*, *Dipsacus pilosus*,
Polygonum aviculare, *Petroselinum segetum*, *Tanacetum officinale*.

(4) Pastures (dry, sandy, or calcareous : grazed) :—

Carduus acaulis, *Spiraea Filipendula*, *Brachypodium pinnatum*,
Carduus eriophorus, *Scabiosa Columbaria*, *Galium verum*,
Senecio erucifolius, *Ononis spinosa*, *Linaria vulgaris*,
Campanula rotundifolium, *Pimpinella Saxifraga*, *Filago germanica*,
Carlina vulgaris, *Euphrasia officinalis*, *Gentiana Amarella*.

(5) Meadows and Damp Alluvium :—

Phleum pratense, *Scabiosa succisa*, *Leontodon autumnalis*,
Aira caespitosa.

(6) Swamp-Woodland :—

Angelica sylvestris, *Eupatorium cannabinum*, *Juncus effusus*,
Pedicularis palustris, *Anagallis tenella*, *Juncus acutiflorus*,
Galium uliginosum, *Parnassia palustris*, *Juncus lamprocarpus*,
Epipactis palustris, *Hydrocotyle vulgaris*, *Eleocharis palustris*,
Gymnadenia conopsea, *Oenanthe Lachenalii*, *Molinia coerulea*,
Orchis incarnata, *Calamagrostis epigeios*.

(7) Sub-aquatics of Ditch and River-bank :—

Epilobium hirsutum, *Rumex Hydrolapathum*, *Glyceria aquatica*,
Epilobium parviflorum, *Oenanthe fistulosa*, *Typha latifolium*,
Lythrum Salicaria, *Sagittaria sagittifolia*, *Typha angustifolium*,
Lysimachia vulgaris, *Sparganium simplex*, *Hypericum quadrangulum*,
Sium latifolium, *Sium angustifolium*, *Polygonum mite*,

[1] The immense output of this submerged vegetation is only noticed when parts of the navigable stream are cleaned by drag-knife in mid-July ; the material rising to the surface as cut, to be pitch-forked into barges.

Lycopus europaeus, *Achillea Ptarmica*, *Rumex maritimus*,
Scutellaria galericulata, *Ranunculus Lingua*, *Catabrosa aquatica*,
Epilobium roseum.

(8) Aquatics of open water:—

Oenanthe fluviatilis, *Nymphaea alba*, *Elodea canadensis*.
Limnanthemum nymphaeoides,

(9) Cultivated Fields and Allotments:—

Solanum nigrum, *Stachys arvensis*, *Vicia tetrasperma*,
Euphorbia Peplus, *Mentha arvensis*, *Cuscuta europaea*,
Polygonum lapathifolium, *Trifolium arvense*, *Valerianella dentata*,
Atriplex hastata, *Mentha sativa*, *Anthemis Cotula*,
Mercurialis annua, *Medicago maculata*, *Medicago sativa*,
Silene inflata, *Sinapis nigra*, *Linaria Elatine*,
Chenopodium rubrum, *Linaria minor*, *Linaria spuria*,
Lepidium ruderale.

(10) On wall-tops:—

Sedum reflexum.

(11) Garden Trees and Shrubs (flowering) in general cultivation:—

Buddleia variabilis, *Hypericum calycinum*, *Clematis Jackmanni*,
Spiraea ariaefolia, *Spiraea Lindleyana*, *Cistus ladaniferus*,
Magnolia grandiflora, *Phlomis fruticosa*, *Periploca graeca*,
Rhus typhina, *Fuchsia gracilis*, *Philadelphus* (sp.),
Olearia Haastii, (*Catalpa bignonioides*).

(12) Plants on the June list now culminating:—

Epilobium angustifolium, *Heracleum Sphondylium*, *Nuphar luteum*,
Senecio Jacobaea, *Spiraea Ulmaria*, *Potamogeton natans*,
Carduus lanceolatus, *Malva sylvestris*, *Potamogeton lucens*,
Rubus fruticosus (forms), *Ranunculus fluitans*, *Ranunculus circinatus*.

It may be noted that the range of error in first-flowering records is now quite as wide as in the case of the flowers of early Spring; this being the result not only of questions of sunlight and amount of water-supply, but in some cases also of the stored reserves or even floral exhaustion of the previous season. Comparison of a few representative types, noted in the same situation in successive years gives:—

	1921 (June drought)	1922 (Wet Summer)	1923 (Cold Spring)	1924 (June flood)	days range
Clematis Vitalba	July 5.	July 7.	July 12.	July 10.	7
Humulus Lupulus ♂ . . .	July 15.	Aug. 5.	Aug. 21.	July 17.	37
Artemisia vulgaris	July 13.	July 31.	July 17.	July 10.	21
Sonchus arvensis	July 4.	July 11.	July 18.	July 12.	14
Lycopus europaeus	July 8.	July 24.	July 26.	July 15.	18
Butomus umbellatus	June 16.	June 16.	July 16.	July 11.	30
Sagittaria sagittifolia . . .	June 30.	July 5.	Aug. 2.	July 17.	33
Limnanthemum nymphaeoides .	June 30.	July 18.	July 16.	July 20.	20
Oenanthe fluviatilis	June 16.	July 5.	June 27.	July 1.	19
Calluna vulgaris	July 22.	July 26.	July 31.	July 22.	9

The average of these 10 plants gives again just 3 weeks (20·8 days).

While Midsummer may be said to end at mid-July, it is possible to extend the period for another fortnight, as conveniently marked by the flowering of the Heather, which again coincides with the early corn-harvest, normally beginning in the last week of the month. Hence *Calluna* may be taken as a key-plant for this time of the year, marking the close of the growing period.

Thus it will be seen that *Clematis* and *Calluna* as woody deep-rooted plants show little variation; but the Hop, which requires to make new subaerial shoots in the close competition of the hedgerow during May and June, may be very late when climatic conditions fail in these months. *Artemisia* as a perennial herbaceous plant approaches the normal range of 3 weeks. *Sonchus arvensis*, as a perennial weed of corn-crops, possibly expresses the effect of climatic changes most nearly, since other conditions for its growth are fairly equal. Water-plants are most delicately adjusted to their special environment; but it is interesting to note that while the amount of vegetative extension in a season may vary enormously (*Oenanthe*, *Sagittaria*), the time of flowering, even of only a few strays, is little affected; though in the drought of 1921 all were conspicuously early.

VII. HIGH SUMMER, HARVEST, AND DROUGHT (August)

In a district already nearly denuded of the original woodland, with broad expanses of grassland and cultivated ground on predominantly heavy clay soils or light sand, the heat of summer necessarily implies some degree of drought, as the soil-water evaporates even faster than it can be replaced by normal rainfall. When, as is often the case, the rainfall is below normal, drought immediately supervenes: clay soils crack, sandy soils blow dusty; only in the alluvial flood-area do the meadows remain moist and green as the river is maintained at head-water between the Locks. Parched fields and dusty hedges become the commonplace of the countryside; mown fields bleach out in absence of rain; corn-fields dry out as the crop matures; thinly covered woodland and forest-plots dry out also, and the subordinate vegetation takes on a distinctly xerophytic aspect. Summer plants, enduring great heat and desiccation, as migrants from Central and South Europe, begin to predominate; and such weeds of human association give a new aspect to waste and roadsides. Only in damp woodland a few shade-enduring plants continue to flourish; though in the open swamp and along ditches and river-bank, with enhanced summer temperature and still abundant water-supply, aquatic vegetation is now at its optimum, and new forms come on, the more luxuriant as the weather is the hotter, and drought continues under unclouded sun.

The last week of June, and the early part of July, already mark the beginning of the change, as a great number of plants break out into bloom, whether conspicuously xerophytic or highly specialized aquatics, as the leading representatives of a hot summer vegetation, now free from possibility of damage by frost. The duration of the dominance of such vegetation may be considered as extending from mid-July to mid-August, as the first touches of frost may be felt at the end of the latter month. This element, in what passes as the indigenous flora, is thus at its optimum in high summer, but it has to solve the problem of winter-perennation. Such plants are characteristically (1) Summer annuals, (2) Rosette-biennials, (3) Types with deep-running rhizome, or (4) Aquatics, also rhizomatous and persisting well below the range of winter frost and ice. Conspicuous forms in these several categories include—(1) Poppies, Polygonums, and Chenopods; (2) Thistles, Docks (*Rumex*) and *Dipsacus*; (3) Lianoid herbaceous plants, as

5. *Oenanthe fluviatilis*, in the Wolvercote Stream, Port Meadow, July 20, 1923.

6. *Oenanthe fluviatilis* with *Nuphar*, flowering on the mud, Medley, July 9, 1921.

Calystegia, *Convolvulus*, *Solanum Dulcamara*, *Bryonia*, *Humulus*; (4) *Nymphaea*, *Nuphar*, *Butomus*, *Sagittaria*, *Limnanthemum*, *Hydrocharis*, &c. Many of the more xeromorphic of these forms come on and grow quite as well or even better in a wet season; but they owe their continued dominance to the fact that they endure the drought characteristic more or less of possibly two summers out of three. On the other hand, some of the aquatics flourish and flower the more as the heat becomes tropical (*Sagittaria*, *Limnanthemum*, *Nuphar*).

With the final harvesting of the Hay-crop, and its storage in more or less efficiently straw-thatched ricks, the pastures and their primary flora come to the end of their seasonal history; and any slight aftergrowth of grass and herbaceous flowering forms is of very minor and subsidiary importance; many are given over to grazing, and even in the water-meadows which may carry a second crop of grass, the latter consists practically entirely of vegetative shoots. Where not on the alluvium the fields bleach out. Grazing pastures similarly show a dried top-herbage, giving them a summer-worn appearance, and the floral effect of hedgerows and roadsides soon disappears. The season has undoubtedly turned; and after the Midsummer period (extended to mid-July), vegetation presents a predominantly dull mantle of green, enduring exposure to summer heat, but with little new to come beyond the general ripening of fruits.

The latter half of July is devoted more particularly to the ripening of the corn-crop, and the general vegetative progression of root-crops; the former requiring maximum sunshine and heat, as the cereals are all of southern and even sub-desert origin; the latter maximum sunshine, but also abundant rainfall. The two types of crop are thus to a certain extent complementary, and what is lost on the one may be made up on the other.[1] In a favourable hot and dry season (1921) winter-sown oats and early wheat may be fully harvested before the end of the month. Beans are similarly harvested from the last week of July. All such fields when cleared leave bare stubble, with no special growth, and the sooner they are ploughed for the next crop the better. The last weeks of July mark a distinct epoch in the flora, as significant in cool and wet seasons as in hot and dry; since the work has been done in preceding months. In the latter case the immediate giving over of the flora to summer xerophytes is obvious; but in a cool season a distinctive summer flora is equally characteristic. In these weeks practically all the plants that are left to blossom do so; hence the few plants that remain to come on in August and September acquire a special interest. Though heath-land is locally deficient, the beginning of this period may be dated from the first flowering of the Heather (*Calluna*).

By the beginning of August summer is well advanced,[2] the sun is above

[1] Wheat is still the key-crop, to the growing of which all other agricultural operations are subsidiary, as being of primary necessity for human food, giving a stable product, and still the most reliable in all seasons, though nearing the limit of its geographical range. Suggestions and attempts at replacing it as a primary crop by the cultivation of the Sugar Beet introduce a new set of problems in arranging the labour-schedule for the year. Beet-growing also demands special care in harvesting the crop, and implies the existence of special factories requiring expensive machinery, with added problems of transport. The produce has only a secondary value as feeding-material, and will not keep indefinitely. Beet can be only cultivated in this country on a still narrower margin, and a slight deterioration in the crop due to climatic causes, especially drought or lack of sun, may eliminate all chances of profit. The risk of fruit-farming is even greater; the English climate has its limitations, and these become the more emphasized in the cultivation of non-indigenous plants.

[2] The last week of July, it may be noted, sees the end of the London 'Season', though the University Term had closed down with the onset of the Hay Harvest. Schools break up, and there is a general feeling that the year is getting over; people generally begin to think of 'holidays' as affording a break before the beginning of another winter. In recent years this feeling has become an obsession. This is by no means a reflection on the social scheme, so much as it marks the direct inheritance of a people reared in country habits, whose ancestors three generations or so back were probably all on the land; as London Society is at bottom based on the manners and customs of an

the horizon for 15 hours, with an average of 6 hours a day bright sunshine, and the possibility of 11–12 in one day ; though the day loses 2 hours in the course of the month. The average daily shade-temperature is about 60° F., with a range commonly to 70°–80° in the shade, and 130°–140° in the sun. Conditions of temperature and light are still at an optimum ; the limiting factor in every department of the flora is *water-supply*. Though the rainfall may be at the rate of 2–4 in. per month, this may alternate with periods of desiccation by hot sun and continued NE. and NW. winds, which make for spells of 'fine summer weather' ; but much of the rain in heavy falls is run off to the river by surface-drainage. Surface-streams in dry spells tend to run out, and deficiency of water may lead to severe drought. The conservation of soil-water becomes the controlling factor in woodland, pasture, and arable land ; only in the vicinity of the river, its irrigation-channels, ditches, and low alluvial flats, can the supply keep pace with the demands of vegetation. In this way the aquatic flora now attains a predominant interest in the plant-story, to the exclusion of other types of vegetation, all now more or less perennating or enduring the summer exposure, more especially as the temperature of the water continues high throughout the month.

Beyond the culmination of high summer in July, August can only continue the scheme with (1) *failing light*, now definitely on the down grade ; (2) failing water-supply, implying drought—less commonly the converse case of too much wet (1912, 1922) ; (3) the exhaustion of many forms in fruit production, and consequent diminution of the floral effect ; (4) but in damper areas the beginning of an *aftermath* vegetation, as conditions of early spring are again approximated, though without the spring flowers. Otherwise many plants of early summer begin to bloom again, on new vegetative growths, and a new crop of ephemerals may flower from the first seeds of the year. These plants then mingle curiously with the xerophytes and forms of the waste residual over the summer season, cf. :—

Lamium album,	*Plantago lanceolata*,	*Viola Riviniana*,
Ranunculus repens,	*Senecio vulgaris*,	*Capsella Bursa-pastoris*.

Hence much of the floral review is a repetition of that of July ; and biologically the month indicates the beginning of a dragging out of the summer season in its gradual decline—much as April was the month of dragging winter—as another period of inter-seasonal 'marking time', after the recovery of the year's crops and before facing the perennation problem of the coming winter. This period, even more marked in the vegetation of Central Europe and the Mediterranean region, has been traditionally consecrated to holiday-making and the carrying out of work implying new initiative, even if only in the form of predatory wars.[1]

older land-owning class ; though the idea may be intensified by education on the lines of a continental or Mediterranean civilization in which the resting period of a hot summer is even more insistent. The feeling, subconscious or inherited, tells that the growing period of the year is over ; everything that will grow has grown ; all the flowers that are coming out are out (with few exceptions) ; that is to say, the plant-work of the year is settled for good or ill, and nothing remains but to take the consequences, to gather in what there may be and take things as the gods provide. The effort of the year has been made, and Aug. 1 sees the year set, the season over, and the Harvest usually in full swing, only awaiting completion and the gradual fall of the year. The evenings begin to show a closing in at an increased rate, as a warning not to delay too long. Hence August, which sees the completion of the Harvest, and hard work with hope of remuneration for the food-producers, now presents a general holiday-aspect on the part of the food-consumers ; holiday festivities formerly following Harvest being remembered when the toil to which they were the natural reaction is forgotten.

[1] With food-supplies secured and biological conditions favourable, man becomes actively predatory, or seeks for some new method of employing his time. Aug. 4, 1914, affords a conspicuous illustration of the former in modern times. The last stage of decadence of this acquired instinct is traced in the attraction of the moors for shooting (Aug. 12), and the stubbles (Sept. 1). The com-

Aug. 1 (*Lammas*) with its adjacent Bank Holiday (dedicated to St. Lubbock) may be taken as a central and representative date. In woodland formation the high forest with continuous canopy maintains its photosynthetic work unaffected. The trees display a sombre mass of grey-green, with uniform monotony, but with little show of fruit and none of flower (samaras on Ash and *Acer*, nuts on Beech, *Castanea*, and Oak, but nothing at all on Elms, Poplars, and Willows; more conspicuous fruits occur on planted *Aesculus*, Sycamore, Plane, and *Juglans*, as also on Conifers as *Pinus*, *Larix*, and *Pseudotsuga*). *Castanea* has flowered out, *Clematis Vitalba* and Honeysuckle remain, though in small quantity. The underwood, where of dense Bramble and Bracken, is little affected. Rubi are flowering out, and the Blackberry crop now growing is dependent on fine weather in July: the first fruits ripen on *R. caesius* and allied forms. The first Elder-berries turn colour; the Mountain Ash (particularly in garden-cultivation) becomes spectacular with scarlet fruit; the berries of *Viburnum Lantana* turn from scarlet to black; nuts, still immature, may be conspicuous on Hazel, but few flowers break the green mantle of the undergrowth. *Teucrium Scorodonia* and intrusive *Epilobium angustifolium* are alone characteristic. *Scilla* has now shed seed, though green capsules still persist in shaded situations; other Spring forms are now perennating under ground. Where the soil has little water-content, *Mercurialis* and smaller herbaceous plants as *Primula*, *Viola*, *Veronica officinalis*, shrivel up, or are left as greatly diminished strays. Where moisture remains, these last forms continue to vegetate freely, as *Viola Riviniana* may come into bloom again. Only in the clearings do herbaceous plants still make a show. In dry situations on clay, xerophytes predominate, as—

Carduus lanceolatus, *Dipsacus sylvestris*, *Epilobium angustifolium*,
Stachys Betonica, *Arctium minus*, *Erythraea Centaurium*,
Calamintha Clinopodium, *Senecio Jacobaea*, *Serratula tinctoria*.

In damper tracts near surface-exudation—

Carduus palustris, *Angelica sylvestris*, *Hypericum quadrangulum*,
Lysimachia Nummularia, *Campanula Trachelium*, *Scabiosa succisa*.

Woodland climbers include—

Solanum Dulcamara, *Lonicera Periclymenum*, *Clematis Vitalba*,
Bryonia dioica, *Tamus communis*, *Vicia Cracca*.

Later woodland grasses—

Bromus asper, *Brachypodium sylvestre*, *Aira caespitosa*,
Festuca gigantea, *Calamagrostis epigeios*.

Liana-forms particularly culminate in hedgerows, becoming especially dominant as these have been recently cut back, and covering the regenerating thorn-spray and Elder shoots—

Solanum Dulcamara, *Humulus Lupulus*, *Calystegia sepium*,
Bryonia dioica, *Galium Aparine*, *Tamus communis*,
Convolvulus arvensis.

Dry, sandy, and heath-land gives—

Calluna vulgaris, *Carlina vulgaris*, *Brachypodium pinnatum*,

and woodland-swamp continued in damp hedge-bottoms—

Spiraea Ulmaria, *Eupatorium cannabinum*, *Epilobium tetragonum*,
Angelica sylvestris, *Calystegia sepium*, *Pimpinella magna*.

mencement of Partridge shooting (Sept. 1) implies that the harvest is over and the stubbles bare. In view of frequent late harvests this date might be preferably Sept. 15, or even Oct. 1.

More open swamp—

Pedicularis palustris, *Parnassia palustris*, *Oenanthe Lachenalii*.

Hedge-banks, drying out, present xerophytic Compositae—

Inula Conyza. *Helminthia echioides*;

Labiates as—

Stachys Betonica, *Ballota foetida*, *Calamintha Clinopodium*;

Umbellifers as—

Pastinaca sativa, *Heracleum Sphondylium*, *Conium maculatum*;

while the sequence of the Keck-type of Hedge-Umbellifer is maintained by *Torilis Anthriscus* and *Sison Amomum*.

Hay-fields on dry soil present few relics of the early crop recovering after the removal of the shading dominants—

Trifolium repens, *Trifolium pratense*, *Plantago lanceolata*,
Hypochaeris radicata, *Leontodon hispidus*, *Pimpinella Saxifraga*;

with *Knautia*, *Centaurea nigra*, and especially on the damper alluvium—

Silaus pratensis, *Sanguisorba officinalis*, *Lathyrus pratensis*,
Angelica sylvestris, *Heracleum Sphondylium*, *Spiraea Ulmaria*,

and abundant *Leontodon autumnalis* to come on.

On sandy soil and gravel with greater retention, or especially on railway banks with deeper water-supply, the floral output may be considerable—

Campanula rotundifolia, *Knautia arvensis*, *Linaria vulgaris*,
Carduus acaulis, *Centaurea Scabiosa*, *Convolvulus arvensis*,
Carduus eriophorus, *Senecio Jacobaea*, *Achillea Millefolium*,
Daucus Carota, *Lotus corniculatus*, *Thrincia hirta*.

The turf of roadsides and dry pastures may be burnt brown; the grasses reduced to perennating rhizomes, in which green patches of the foliage of deep-rooted forms and rhizomatous xerophytes are now conspicuous—

Achillea Millefolium, *Hypochaeris radicata*, *Plantago media*,
Plantago lanceolata, *Rumex Acetosa*, *Trifolium repens*,
Trifolium minus, *Galium verum*, *Trifolium fragriferum*,

still with Daisies and Dandelions, familiar as the enduring weeds of garden lawns.

Only in the lowest flood-meadows do the grasses continue to grow rank and thick (a foot or more deep), where the ground remains at the water-level, as a second crop; but these, again, show active vegetative growth only, with no flowering stages.

The closely grazed damp turf of the southern portion of Port Meadow still remains green and retentive in driest seasons, with an interesting flora of closely cropped diminutive forms of—

Myosotis palustris, *Apium nodiflorum*, *Oenanthe fistulosa*,
Veronica Anagallis, *Ranunculus Flammula*, *Prunella vulgaris*.

Such permanently wet stations grade into the damp ditch and the margins of water-courses, now full of rank vegetation, from the Great Water Dock (*Rumex Hydrolapathum*) 6–8 ft., *Sium latifolium*, 6 ft., *Spiraea Ulmaria*, 4–5 ft., *Scrophularia aquatica*, 6–8 ft., *Epilobium hirsutum*, 5 ft.—

Sparganium ramosum, *Sium angustifolium*, *Ranunculus Lingua*,
Sagittaria sagittifolia, *Oenanthe fistulosa*;

and along the more open river-margin—

Lysimachia vulgaris, *Lythrum Salicaria*, *Butomus umbellatus*,
Alisma Plantago, *Polygonum amphibium*, *Sparganium simplex*.

7. *Nuphar, Limnanthemum,* &c.; Medley, July 27, 1923.

8. *Alisma*, *Sparganium*, &c.; Medley, July 27, 1923.

Subsidiary forms include—

Lycopus europaeus,	*Scutellaria galericulata*,	*Apium nodiflorum*,
Myosotis palustris,	*Achillea Ptarmica*,	*Mentha aquatica*,
Bidens tripartita.		

Deeper streams fill with trailing submerged Potamogetons (*P. lucens*, 6–8 ft., *P. perfoliatus*, 6–8 ft., *P. flabellatus*, 12 ft., *P. pectinatus*), *Elodea*, *Myriophyllum*, and the ribbon-leaves of *Scirpus lacustris* and *Sagittaria*. *Nuphar* grows rank in shallow water, flowering and fruiting freely; *Nymphaea* in more quiet ponds and backwaters, is now local, and much less in quantity.

The most conspicuous floral display on the river is afforded by the Villarsia (*Limnanthemum nymphaeoides*), in favourable seasons covering broad stretches of shallow water (1–2 ft.), which may appear as yellow as fields of Buttercups (Medley, 1921) with the fragile ephemeral blossoms only at their optimum at midday. Ponds of standing water mantle with *Lemna* (sp.), *Callitriche*, or the bronzed fronds of *Azolla* in open insolation.

The characteristic features of the water-side in late July is the flowering of *Glyceria aquatica*, the only grass now at its flowering optimum, to be followed in late August by the brown plumes of *Phragmites*. The river-bank is gay with tall purple spikes of *Lythrum Salicaria* (especially where out of reach), and wavy masses of purple *Epilobium hirsutum*, rolling in the breeze, with white *Spiraea Ulmaria*. *Typha* is fruiting, and increasingly conspicuous as its spikes darken; *Sagittaria* is characteristic along the edge of gravel reaches, flowering among the sub-aerial foliage-leaves; *Limnanthemum* is more local, confined to heated shallow and muddy reaches of the river (Medley, Binsey, Pink Hill); *Azolla filiculoides* is established in ponds at Radley and Wolvercote.

With such a wealth of material and variety of type, in stations least interfered with by man—whether flowering on the bank, left stranded on mud-flats, emerging from shallow water, floating on the surface, or rising from deep water, dragging in the flow of a strong current, wholly submerged or freely drifting, or again only to be classed as sub-aquatics of the water-side and swamp—the centre of attraction passes to this remarkable aquatic flora, so highly specialized for extreme conditions of herbaceous growth, and including representatives from isolated archaic families (*Typha*, *Alisma*, *Butomus*, *Sparganium*) as well as northern strays of essentially subtropical and tropical series (Nymphaeaceae, Gentianaceae, Aroideae, Lythraceae, Onagraceae).

The development of this class of vegetation requires to be examined from the water rather than from the land. In extreme forms it presents the case of practically an attempt at simulation of an algal stage of existence,[1] with implied limitation of light-supply, inferior food-salt supply, and scanty gas-content, which more than any other available type of plant-association diverges most widely from the general conception of the main-line of plant-evolution, as culminating in the sub-aerial type of woodland vegetation on the land-surface of the present world. Being thus most widely divergent from what passes as the normal land-plant, and living under conditions of distinct biological inferiority, aquatic forms are as a necessary consequence even more sensitive than the general run of land-plants to changes in their environment.

As the water-level falls in ditches and river, the plants tend to fill all available space, and shallow reaches become blocked with massed vegetation

[1] Bushy growths of *Potamogeton pectinatus*, *P. lucens*, and *Myriophyllum*, particularly when covered with silt in the river, or a fluffy brown coating of Diatoms, present growth-forms curiously suggestive of larger Phaeophyceae (Sargasseae, Cystoseireae).

which may impede navigation. This may be cleared periodically by human agency in the main river and mill-streams; but there can be little doubt that if the river were left in its original unlocked condition, most of it would drain away in hot summer months, and the bed be completely filled, even in a single season, with the summer growth of aquatics to the limit of the available water-supply and increasingly restricted retentive substratum.[1] There seems to be every probability that this is what happened normally in pre-historic times, allowing free inter-communication on foot throughout the district in the summer months. Such summer shallows encouraging invasive woody forms would soon return to the original scrub-swamp,[2] to be more or less cleared by winter torrents, were it not for the effect of human occupation in clearing the river and alluvial pastures of anything but their present herbaceous occupants.

Harvest. The Corn Harvest begins normally in the last week of July: only in exceptional years (1921) is it wholly completed before the first of August; though again the Hay Harvest may overlap, as the last Alluvial meadows are often not cut before the middle of the latter month. Winter-sown Oats is the first crop taken, and usually harvested in the last week of July, together with Beans and any Rye that has not been cut for green fodder. Beans may be left standing as they are less subject to damage. Oats are usually cut by machine (self-binder); but both Oats and Rye have been seen cut on small-holdings by the older laborious method of 'hook and stick'. The Wheat Harvest follows, about a week later, normally in the first week of August, and in average seasons is usually completed by the middle of the month; but in late years may extend well into September. The cutting of Spring-sown Oats and Barley may be delayed to the last. The harvesting of a large field of Wheat, cut by machine, and set up in shocks in one day with little labour, is still the most picturesque scene of the countryside. In brilliant sunshine the bleached expanses of waving corn fall rapidly before the self-binder drawn by three horses, at the rate of about an acre an hour, and the sheaves are set up in shocks of 8–10 or 12. As the last piece in the centre of the field is cut, rabbits and hares rush out to the excitement of the assembled workers. Sheaves are later collected into ricks in the farm rick-yard and thatched with straw, to be threshed out when convenient. The stubbles are left bare and bleached showing little further growth of weeds.

In olden times the Harvest was delayed over the month of August owing to the time required for hand-labour.[3] Hence much corn was cut over-ripe. A local practice of cutting Wheat before it was fully ripe with the smooth hook, and allowing it to exhaust the stems in the shock, is accorded by Plot (1677), may indicate poor husbandry; but it is safe not to delay if the weather is fine. Wheat was preferably cut by saw-edged sickle, as the highest expres-

[1] The main river immediately below and above the town only requires a minimum depth of 3 ft. 9 in. for purposes of navigation. Local mill-streams (Wytham Stream, Hinksey Stream, and the 'Old River' at Medley, have been much neglected. In past times they were kept clear to supply power for mills at Wytham, Botley, Osney, and the City. They soon fill up with *Sparganium* and *Glyceria aquatica*; deeper pools cover with *Potamogeton natans*; and where reed-growths are not kept down by cattle, the stream may vanish from sight. Present blocking of the free current is due less to vegetation than to accumulation of human debris as tin cans, etc. Similar blocking of streams near the City in the Middle Ages, leading to disastrous floods and plagues, was compensated (1517) by the cutting of special ditches in the meadows below the town (Plot). The modern management of the river tends to increase the depth and scour of the main stream, and many minor branches have been allowed to run dry in quite modern times (Botley and Abingdon Road). Osney Lock was reconstructed after the great flood of 1894, Godstow Lock and the Weirs, 1923; the important Lock and Weir at Iffley, 1923–4 has an increased effect, and will be followed by a clearing of subsidiary streams.

[2] The Oxford 'Dane Mound' probably expresses the limit of river navigation, even in the winter months, some thousand years ago.

[3] Cf. Shakespeare, 'Tempest.'—'Ye sunburnt sickle-men of August weary.'

sion of neat human work.—The sheaves, representing an armful of the reaper, to be bound with the length of straw, and the corn held and cut carefully by a pulling movement of the sickle in order to avoid shaking any grain from the ears.[1] Sheaves were set up two at a time, more or less rafter-wise, formerly in shocks of 10 for convenience of estimating piece-work; as also, it is suggested, for throwing out one sheaf from each shock for tithe. At the present time sheaves are dropped by the machine, and shocks are set up to facilitate collection by cart. In wet weather they are protective against damage by rain; though increasingly liable to depredations by birds.[2] In the wet summers of 1922–4, shocks were in some cases standing out for 2–3 weeks. The self-binder, cutting a 4 ft. breadth, throws out sheaves with little care at 7–8 yards, and wheat is again preferably cut early before the grain loosens.[3] Seeds of many weeds are also knocked out in the process of cutting; this applies particularly to *Avena fatua*, all the bristly fruits of which are shed, leaving the sheaves clean.

When Harvest is over the general aspect of the country is that of being completely shorn; emphasizing the wholly artificial nature of the local formations, and the extent of modern cultivation. The general effect is however agreeably lessened by the great abundance of trees in the hedges, which still obscure wider views of the landscape (particularly Common Elm in clay areas, and pollard Willow on the Alluvium). On the whole the countryside is now to be considered as a garden, more or less carefully kept; and one begins to wonder what would be the effect if all the crops were allowed to run to waste, and become overgrown with weeds.

[1] The sickle is extinct, but older people remember having seen it used, or have tried it.

[2] Near habitations the fields are visited by droves of sparrows which migrate from the town area over the weeks of harvest. As many as 30–50 have been seen on one shock, picking grain from all exposed ears: they return to town haunts in the last week of September.

[3] While up-to-date farmers employ a tractor self-binder, on the other side of the hedge (Cowley) smallholders may be seen fagging Oats with hook and stick. The same old method was employed for badly laid wheat (1924).

Varieties in cultivation include forms of 'Yeoman' and 'Little Joss.' A well-grown wheat-ear averages 50 grains (40–60), and 500 dry grains measure a fluid ounce, or 10,000 to a pint, and 640,000 to a bushel. The output of an acre averaging 30 bushels crop is approximately 20 million grains. The output of Wheat for Great Britain (1922) is given as 64 million bushels, or approximately 40 billions; as the population requires about 5 times this as food supply, the annual demand is for some 2×10^{14} living wheat embryos and their seed food-supply. This in conjunction with the 17 million cattle and 9 million sheep annually slaughtered in this country for food, as representing about one half the meat-supply, gives some idea of the expenditure of 'lower forms of life' requisite to maintain the human population at its intellectual level.

An average crop of 30 bushels to the acre works out as some 4,000 grains to the square yard, or 450 to the square foot, which represents the yield of 9 good ears; or, allowing for average tillering, the output of 3 wheat-plants. Wheat is commonly sown at 2 bushels to the acre, or approximately 30 grains on the square foot, to give a smothering crop, in which the seedlings afford mutual protection over frosts and storms of winter. This may imply a wastage of 90 % of the grain in sowing.

If two bushels are required for planting an acre, giving an average yield of 30 bushels, the return is 15-fold, and would represent 450 grains to the square foot. This would approximate again 9 ears, or one ear 15–16 sq. inches. At this rate one grain would represent the amount of solar energy utilized by man for producing photosynthetic food on some 100 sq. mm., or one-fifth the area of a postage-stamp. Such data, again, appears to imply a considerable wastage in cultivation and harvesting.

A good crop of wheat gives 20 ears to the square foot; or, drilled at 7 in. about 10 ears to a foot run of the drill. It would hence appear that the wastage of cultivation and harvesting is still 50 %, allowing, that is to say, for thin spaces in the crop, failure in the drills, hedgerow waste, trampling and damage in cutting and moving the sheaves, as well as loss by birds and rodents. In such case traditional stories of bumper crops on the same ground may reflect better husbandry, rather than anything in the yield of the variety of grain.

Similar defective results are given by the Barley crop. A good field of Barley will give 30 ears to the square foot, or more. Two-rowed barley, averaging 30 grains to the ear, and 400 dry grains to the fluid ounce (8,000 to the pint), should give a crop of 30 bushels with only 12 ears to the square foot. Six-rowed Barley, 400 grains to the oz., averaging 50 grains to the ear, should give 60 bushels at 14 ears to the sq. ft.

The general average taken as 30 bushels per acre is distinctly low: 4 quarters (32 bushels) would be regarded as a poor crop, 5–6 quarters more satisfactory, and 60 bushels has been obtained by careful husbandry on good ground, though possibly not within the local area.

Were a 10-acre field, producing some 200 million good healthy seeds with viable embryos, left untouched, the crop would be beaten down by autumn rains, and practically the whole of the grain shaken out and taken by birds. Few would germinate or survive the winter if not ploughed in. The few that might do so in cracks of the soil, coming up the next season as 'Voluntary Wheat' in a dense weed-crop, would be further diminished in the succeeding year. In three years the ground would be mainly covered by coarse grasses, and no trace of the wheat be left. Regression to woodland would then begin to set in.

Occupiers of small-holdings, lacking the means to pay for expensive machinery, or any place to house it when not in use, fall back on simpler and more ineffective methods of husbandry. The land is cropped more extensively in strips, and with less attention to cultivation is often extremely weedy, as compared with the well-cleaned fields of farmers using good methods of rotation on a larger scale.

Standing crops may be full of still-flowering—

Carduus arvensis, *Convolvulus arvensis*,
Papaver Rhoeas, *Matricaria Chamomilla*,
Aethusa Cynapium, *Alopecurus agrestis*.

Again, as the Hay Harvest disperses many of the weeds of the hay-crop, so many plants of early summer fruit out in great quantity in early August, and are distributed over fields and along hedgerows in harvest operations.

All unoccupied sites and waste-heaps are at their optimum in Harvest-time, as the fruiting of their commonest weeds coincides with that of the cereals, especially—

Carduus arvensis, fluffing out, *Sinapis arvensis*,
Heracleum Sphondylium, *Raphanus Raphanistrum*,
Anthriscus sylvestris, *Rumex crispus*, *R. obtusifolius*,
Hordeum murinum, *Agropyrum repens*.

A small-holding, wholly neglected for a season, becomes a dense jungle of all the common weeds of cultivation, and even a greater menace to the land around than a neglected allotment. The wanderer may be attracted at first by the exceptional floral display, but one soon sees the mischief this implies, and the insecurity of tenure on the part of the more valuable human associates. In the immediate vicinity of fine stretches of corn may be found casual waste-heaps, in which within the space of a few feet, over two dozen weeds may be associated with voluntary Wheat, Barley, Oats, and Potato halms (Cowley).

A sample list, checked without moving from the spot—

Artemisia vulgaris, *Capsella Bursa-pastoris*, *Polygonum Convolvulus*,
Achillea Millefolium, *Chenopodium album*, *Polygonum amphibium*,
Alopecurus agrestis, *Medicago lupulina*, *Polygonum Persicaria*,
Agropyrum repens, *Matricaria Chamomilla*, *Rumex obtusifolius*,
Aethusa Cynapium, *Papaver Rhoeas*, *Raphanus Raphanistrum*,
Agrostis vulgaris, *Papaver dubium*, *Sinapis arvensis*,
Chrysanthemum segetum, *Poa annua*, *Trifolium pratense*,
Carduus arvensis, *Polygonum aviculare*, *Trifolium hybridum*,
Urtica dioica.

Data for wastage of cultivation may be open to criticism, but the general result seems to hold. A sample of poor local Wheat (including Radish, Corn Cockle, Barley, and Oats as impurities), thoroughly dried out, gave 600 grains to the fluid oz.; this increases the range per acre by 20 %: e. g. 35 seedlings to the square foot as commonly sown; yet on a local field, drilled in 7-inch rows, wheat-seedlings came up at 30–40 on a foot run of the drill, giving an initial average of plants nearer 60 to the square ft., or just double the previous estimate.

A special case of a dense crop (beyond the local area) gave 356 ears on a sample sq. yard (or 40 to the sq. ft.) at harvest-time: taking poor grains at 600 to the fluid oz., and only 40 grains to poor ears, this works out as a crop carried of about 90 bushels to the acre; but the result on threshing out, including all tailings, was given as 45 bushels to the acre, or again as suggesting an error in taking the produce of the ground of 50 %.

9. Wheat in Shock (var. Little Joss); Temple Cowley, Aug. 17, 1923.

10. Weed-heap by Barley Field; *Carduus arvensis*, *Achillea*, *Chrysanthemum segetum*, voluntary Wheat, &c.; Cowley Small-holdings, Aug. 20, 1924.

Drought implies extreme conditions of the problem of summer water-supply. The severe experience of the summer of 1921 [1] affords the best example within living memory; the dry summer being remarkable, not so much for its extreme heat, brilliant insolation, and drying winds, as for following a similarly dry and brilliantly lighted spring. There was no rain worth mentioning from the end of January to mid-September; a few heavy thunderstorms in August alone lightening the effect of xerophytic conditions. Vegetation stood the strain till Midsummer, but in July and August the results of scanty water-supply were very pronounced, and curiously out of all proportion to local meteorological records. There was practically no rain for 100 days of the summer season, with extreme heat, drying NE. winds, or intense insolation for as much as 15 hours on some days.[2] Such data effectively illustrate the ineffectiveness of such measurements in dealing with a biological problem. Much of the 'rainfall' is undoubtedly dew, a heavy thunder-shower on hot ground leaves no trace in 2–3 hours: the maximum temperatures attained afford little information as to the duration of such temperature, and 'bright sunshine' in efficiency depends largely on the time of day the sun is shining.

Observations on the effect of such long-continued drought on local vegetation, showed that in Woodland, with high-forest in close canopy, little immediate effect is noticed; though many trees, particularly stag-headed Oaks, died off wholly or in part. On gravels there may be water in deeper levels; but on clay (Kimeridge, Oxford) there is no further supply beyond what the ground will hold. Such clays though impervious are retentive; the surface may crack badly, but some water remains, though streams may run wholly dry. Larger deeply-rooted trees, whether on heavy clay or on calcareous soils showed no immediate ill-effects, but smaller forms were conspicuously affected. The Birch in dried tracts became wholly yellow with golden autumnal tints (July 15). The Common Elm also showed its 'yellow boughs' in mid-July. Willows on gravel-soil flagged and shed their lower leaves. Young Sycamore under the canopy of higher trees conspicuously wilted, the leaves drying up on the branches. Young Larch in close-planted plots was yellow in July. The swamp Elder was the first to flag; *Viburnum Opulus* died off on the river-bank as the water-level fell; but the more xerophytic trees as Hawthorn and especially *Prunus spinosa* on dry hedgebanks were the first to shed their foliage. Evergreens shed their previous season's leaves, and Conifers, especially *Pinus sylvestris*,

As plant-forms, both Wheat and Barley are cultivated under very unnatural conditions to give (1) a uniform crop, (2) in close canopy for mutual protection, (3) ears maturing grain at the same time, in order to subserve the general exigencies of agricultural labour. Single plants, under optimum conditions of insolation and water-supply, send up new flowering spikes in succession; in this way one wheat-plant may produce 60–100 ears before exhaustion; lateral shoots sending up ears throughout the summer to September; while Barley plants show even more active continuous growth so long as the water-supply is sufficient.

[1] The phenomena of plant-life were so conspicuously modified by the drought of 1921, that it, in fact, suggested the advisability of keeping a record of the average condition of affairs to serve as a standard of reference.

[2] The Radcliffe Records give:—

	Total Rainfall. Inches.	Mean max. temp. (of all days).	Max. shade temp. (on any one day).	Max. sun temp. (on any one day).	Total hours of bright sunshine.
June	·340 (−2·034)	70·6 (+3·04)	85·2 (+6·5)	146·4	244·85 (+52·29)
July	·285 (−2·292)	78·9 (+8·23)	89·1 (+7·2)	149·5	258·85 (+68·83)
Aug.	1·684 (− ·738)	69·5 (+ ·05)	80·6 (+1·5)	137·7	146·10 (−30·44)
Sept.	1·715 (− ·468)	69·0 (+4·29)	83·3 (+9·9)	131·0	171·60 (+30·17)

Radcliffe Observatory Reports, vol. lii; vol. liv, part 1.

Numbers in brackets indicate the gain or loss respectively as compared with tabulated averages for the last 40–70 years: these work out as a deficiency of 5·532 inches of rain during the 4 summer months, a general increase of temperature, and a net gain of 120·85 hours of bright sunshine.

further batches of cones. In these cases the conditions of preliminary leaf-fall more general in mid-September were anticipated. In Woodland clearings the dense growth of Bracken effectively covered the soil, conserving soil-moisture, though eliminating other flora; but in open clearings on clay the herbaceous flora wholly dried up, and the ground was deeply cracked.[1]

In the Pastures on low alluvium the hay-crop was short but fair, drying the day it was cut, and carried the next. The Hay Harvest was completed in mid-June (June 15–21). Higher pastures afforded a scanty crop, and many were not cut at all. In clay soils deep cracks opened up, 4–6 inches wide. On the alluvium after the hay-crop, these gaped down 2–3 ft. to subjacent gravel (Osney Fields). Pasture fields, dried out and bleached, afforded scanty feed for cattle; all excrement dried and accumulated for six months, until fields appeared wholly fouled. This was particularly noticeable on Port Meadow, and again on Goose-pasture at Medley. The cattle fed on the river-herbage, and exposed mud-flats (Port Meadow) were trampled by horses in search of food as much as of water. Dry pastures did not recover green growth until late September; in many cases deep cracks were still in evidence in the succeeding spring. Water-meadows, cut for hay (June 17), and left ungrazed, continued green and afforded a second crop, though scanty, in September (10–12). Many fields did not recover their green appearance until November.

Arable fields under corn showed no injurious effects. Wheat, winter-sown and deep-rooted, more particularly is at home under such conditions: the effect of drought is to shorten the straw rather than to affect the grain; but late spring-sown Barley was but an apology for a crop. The Harvest was hastened; upland fields were cut July 13, and river-gravel areas July 15. The whole crop being harvested before the end of the month. The effect of the heat was shown in the weeds more than in the crop: fields which had been gaudy with Poppies, Radish, and Charlock, in mid-June, cleaned up as the corn yellowed. Arable fields under roots grew weeds in abundance, but the root-crops were conspicuously poor; many fields of turnips a total failure. Mangels only gave good results in the irrigation ditches of the Sewage Farm. In all allotment-areas late-planted potatoes were burnt out of the ground. All vegetables were scarce until late September.

The effects were most marked in the case of aquatic vegetation. The aquatic flora was on the whole deteriorated vegetatively; though in a few cases growing with exceptional profusion (*Sagittaria*, *Limnanthemum*). Hedge-ditches run dry, but retain enough moisture in the silty bottom to maintain semi-aquatics for a long time (*Carex* sp., Grasses, *Scrophularia aquatica*, *Epilobium hirsutum*). Ditches and irrigation channels, full of water in wet weather, may run wholly dry. *Sparganium ramosum* was left stranded on the bank-side a foot above the water-level, as also many Potamogetons normally wholly submerged, and *Polygonum amphibium*. Ditches in Marston Fields were dry for the first time in living memory. The Lower Cherwell was kept up by the lock at Iffley, but ran dry at Gosford; the bed of the stream was dry at Islip Bridge in September. The Thames was only held up between the locks by stringent economy, and the weir steps at Teddington were dry. The fall of such a summer drought is roughly 3 ft. below the normal (Medley, Osney, Iffley), as Flood-level may be 3 ft. above, giving a full vertical range of 6 ft. for the extremes of bank-vegetation (Medley). As the surface-level falls, the current weakens, and extensive exposure of mud appears (Port Meadow), leaving the aquatics

[1] Bagley Wood did not fully recover until Sept. 1922; after heavy rain in August the woodland surface again became saturated, and water began to run in the gullies, though the latter only attained full volume in March 1923.

of shallow water wholly stranded (*Limnanthemum, Nuphar*), to Potamogetons and *Elodea*, with banks of *Oenanthe fluviatilis, Scirpus lacustris* and *Hippuris*, mingled with *Mentha aquatica* and *Lythrum Salicaria*. The mud being deep (3–4 ft.), and highly retentive, all these plants flower out in profusion at increased temperature in the open, attaining their optimum relations out of the water. That this is the more normal swamp-habit of many river 'aquatics' appears from the remarkable behaviour of *Oenanthe fluviatilis, Limnanthemum, Sagittaria*, and *Butomus*.

Oenanthe fluviatilis, commonly seen as submerged fern-like fronds, in 1921 flowered over broad banks, where in previous years it occurred only as scanty traces. In all parts of the district the plant was ubiquitous in flower and fruit; masses loosened from the mud were drifted down stream as the river rose again in Autumn. In 1922, it was difficult to find any good flowering specimens; but in 1923, it was even more abundant, flowering over broad areas of the river-surface (Binsey), suggesting a biennial growth-period from abundant fruiting of 1921.

Limnanthemum covered stretches of water and mud, flowering in yellow expanses, again where flowers are usually obtained only with difficulty. Marked vegetative growth characterized *Sagittaria* which gave a flowering maximum in 1922, as also did *Butomus*. A dense growth of *Hippuris* apparently followed a hot and early spring; it was not repeated in succeeding years; plants being poor and skimpy (1922–3), and even worse in 1924.

With continued desiccation, later in the season failure of the conduction system became noticeable in all sub-aerial portions. *Rumex Hydrolapathum* shrivels and flags in hot sun. *Sium latifolium* was conspicuously poor. *Sagittaria* leaves were burnt brown and dried up, and even the exposed foliage of *Nymphaea* and *Nuphar* dried and curled on the water-surface, suggesting in all these cases the original habit of the forms in shaded Woodland-swamps.

Vegetation of the ditch-side was much reduced and also poor in quality. The Bullingdon, Bayswater, and Northfield Brooks were reduced to merest runnels, in which it was difficult to collect even a bucketful of water. Duck-ponds dried up, leaving a flora of mixed Polygonums and Chenopods with *Rumex* (sp.) on the exposed and cracked clay-bottom.

Extreme drought in July and August is one side of the picture; in other years there may be excessive rain-fall in these summer months (5 in. 1922; 5·06 in. 1879, the record wet summer). Excessive rain may it is true destroy the hay drying in the fields, and may badly lay the corn, just as the stems are getting too old to erect again, as it also spoils garden-flowers. But all these are purely artificial features of human interest, and bear no relation to the indigenous flora.

When the season is wet, heavy rain soaks the woodland base, and Mosses and Lichens revive, and are as good as in the early months of Spring; Fungi also begin to appear (*Phallus*), and Mushrooms are collected from the pastures. The sheeting of driving rain on the heavy full green canopy of woodland, with now but few flowers, is a remarkable sight; and such conditions, combined with high summer temperature and long hours of daylight, acquire a special interest as affording the only opportunity in this part of the world for visualizing the conditions of a tropical rain-forest, even if only on a small scale;[1] and again helping to gain some realization of the conditions

[1] General impressions of such tropical forest are commonly acquired from the highly seasonal monsoon-forests of India, or of pleasant places easily accessible from the sea. The primary forest of the present world is that of the Amazon, described by Wallace as a gloomy region of 1,000 miles radius, the canopy unbroken except at streams and rivers. H. M. Stanley has left a vivid impression of the great equatorial forest of the Congo, through which he cut a way for 500 miles in 1888. (Botanists as a rule do not see the wood for the trees.)

'Take a thick Scottish copse, dripping with rain; imagine this copse to be a mere undergrowth

of such forest-growth from the beginning of time, which have made such plant-forms possible, as they successfully migrated to the land from the sea and solved the problems of photosynthesis in sub-saturated air.

In striking contrast to 1921, as indicating the range of climatic possibility and the chances of the district, the succeeding season (1922) with its remarkably cool and comparatively sunless summer (July and August) affords a conspicuous illustration, as similarly following great heat and promise of drought in May and early June. After this the summer proper seemed to vanish in low temperature (around 60°), cloudy skies and considerable rain throughout the whole of the harvest-season. The rainfall in August was 5 inches (5·11, B.G.O.) with a maximum of 2·398 Aug. 6), and similar conditions were general over the central part of England (hours of bright sunshine, total 111·1, or 63% normal).

The Hay Harvest which had promised well in early June, and even started June 3 for a few fields, was held up and long delayed. Cutting only became general in the third week of July, the last fields were cut Aug. 25, and the single crop was not all saved by Sept. 1. In the alluvial area the later hay-fields were black with *Sanguisorba officinalis*, white over damp stretches with *Spiraea Ulmaria*, and yellow in later weeks with *Leontodon autumnalis*, consisting almost entirely of thick bottom-growth of the aftermath, with abundant foliage of herbaceous plants. The first grasses seeded out, and the two crops of the water-meadows were merged in one (Iffley). Hayfields cut early in the season became vivid green as soon as cut. Grazed pastures appeared shabby by contrast, as the older herbage was incompletely grazed off, and tall weeds flourished.

The Corn Harvest was also late, though the crops were good and clean. Upland Wheat was started July 31 (Oats, Barley, Beans also); but cutting only became general in the middle of August; special efforts to get the crops in, before damaged by rain and birds, being made in the 3rd and 4th weeks of the month. In many fields the wheat remained out in shocks for a fortnight, the stubbles became green, much of the grain was taken by birds, and the last fields were only being cleared on the 1st of September.

The effect on the indigenous flora was less marked and mainly negative. The Woodland maintained its densely green mass unchanged, with abundant Lammas-shoots on Oak and Beech; the regeneration shoots of Oak-coppice being possibly more conspicuously mildewed than usual. Plants of Hedgerows and Woodland clearings flowered and fruited normally, in many cases in astonishing profusion following the heat of the previous season, and there was less death from sheer withering up in wind and sun. There were no premature heat-falls of leaves in July; but with cool nights and morning dews, also fog in mid-August, leaves began to show signs of giving out; though at first only in the case of exotics. The Common Elm presented the first golden boughs July 31, and more conspicuously in mid-August. The first yellow leaves began to fall from Willow, Lime, and Elm, Aug. 25. *Ampelopsis Veitchii* bronzed on exposed walls and chimneys Aug. 18, and *A. hederacea* in places was bright crimson by Aug. 24. Wet weather hastened the autumnal tints and the aftermath period: the dry spell was cut out rather than replaced, and the season turned earlier to autumn. Woodland began to show signs of giving out in the last week of August; shaded *Pteris* was bleaching or bronzing, leaves of *Viburnum Opulus* were purple, and *Tamus* foliage yellow by Sept. 1;

nourished under the impenetrable shade of ancient trees ranging from 100 to 150 ft. high, briars and thorns abundant; lazy creeks meandering through the depths of the jungle. Imagine this forest and jungle in all stages of decay and growth, old trees falling, leaning perilously over, fallen prostrate. Rain pattering down on you every other day of the year; gloom throughout the day, and darkness almost palpable throughout the night. The gloom of the forest is perpetual, the sky one half of the time every day resembles a wintry sky in England.'

The interest of such a non-botanical description of a modern continental forest centres in the fact that it would doubtless have been an admirable account of the conditions of a swamp-forest of the Coal Measures, or even of geological epochs characterized by still older types of Land Flora.

the general approach of Autumn being more than a fortnight in advance of that in the year of drought.

The riverside flora, less developed as water was maintained at Headwater between Locks without any difficulty, pursued its normal course. Extensive rains in August gave the beginning of a rise which promised a flood (total for the month 5·132 in.). Meadows of the Upper Cherwell were under water, Medley Weir was wholly drawn to relieve Port Meadow which was as squashy as it is usually in March. Iffley Fields were 2 in. deep among the grass-roots of the hay-crop and cut windrows. Under these conditions the exceptional aquatic flora was not seen on the mudbanks, and much of the earlier vegetation, adapted to the shallows of early summer, was drowned out. As the river remained high (tail-water over 5 ft. at Iffley Lock), cutting of the weeds was not required; and as the temperature remained low, the sub-tropical luxuriance of 1921 was not renewed. *Oenanthe fluviatilis* was scarce, and *Limnanthemum* conspicuously poor.

Closely comparable phenomena were characteristic of the summer of 1924. The temperature for the greater part of August was under 60° F.; the rainfall was well *below* the average for the month (total 1·934 in.); but it was distributed in constant showers which checked harvest operations and prevented the effective weeding of root-crops. A spell of 3 weeks in August, continued throughout September, destroying the holiday season, excited considerable adverse criticism of the British climate in the daily Press, as one of the most unsatisfactory August seasons on record. This weather is euphemistically described by meteorologists as giving 'Fair intervals'; it is primarily defective in *light-supply*. The working hours of daylight are considerably curtailed at both ends by dense cloud, greatly exaggerating the normal loss of daylight in the month, and thus inducing cool autumnal conditions anticipating the aftermath period. Bright sunshine was recorded as 149 hours; 27 below normal, or 86% of the average (and so far better than 1922). Though unwelcome to the human population and much of their modern introduced plant-associates, such a state of affairs appears as a distinct boon to the primary flora, long responding to similar conditions in past ages.[1] Thus garden-flowers may be ruined, and roses mildewed off without opening; the corn may be deteriorated by standing exposed in shocks for 2–3 weeks, and distinct autumnal changes are seen in the case of introduced trees; but the characteristic feature is the rank and luxuriant vegetative growth of 'weeds' and the herbaceous flora of field and hedgerow: though flowering stages may be less abundant.

Much hay on the Alluvium was still out at the end of the month; the last field in the Iffley area carried Aug. 27. Pixey Mead was cutting in the last week of August, and much of Oxey Mead still uncut. The first fields of Oats, cut July 25 (Cowley), were still in shock Aug. 25; the first Wheat cut Aug. 11, but much still uncut Aug. 26, and little carried. The last field of Wheat was carried Sept. 12, as the last field of Barley was cut, and the first oat-stubbles ploughed (Cowley).

Ampelopsis on exposed house-walls began to go red Aug. 14, and coloration was well-advanced by the end of the month. The first yellow boughs of Elm Aug. 14, were also conspicuous by the end of the month, and yellow leaves showing and shedding freely from Poplar, Lime, Plane, and Plum.

The aquatic flora of the river-bank, following the consequences of the flood of early June, was extremely poor. The river remained high; all Potamogetons and *Elodea* flourished in leafy masses; but the Villarsia was practically flowerless, and flowering *Oenanthe* scanty. *Sparganium* attained full growth only in late August; but *Rumex Hydrolapathum* was at its vegetative optimum, with conspicuously well-developed foliage-leaves and fruiting panicles.

[1] Cf. Shakespeare, 'Midsummer Night's Dream', for description of a wet Harvest-season, an suggested outbreak of Foot and Mouth Disease, 'The nine men's morris is filled up with mud,' etc.

All minor sub-aquatics were poor and scarce: flowering stages in all stations closed down abruptly by Sept. 15, though gardens remained conspicuously gay to Oct. 15.

Flowering Plants (15) August.

(1) Woodland Trees and Shrubs—
Calluna vulgaris.

(2) Herbaceous Perennials of Woodland and Clearings—
Lactuca muralis. (*Colchicum autumnale*).

(3) Hedgerows and Roadsides—
Erigeron canadensis, *Filago minima.*

(6) Swamp Woodland—
Pulicaria dysenterica.

(7) Sub-aquatics of Ditch and River-bank—
Mentha aquatica, *Bidens tripartita,* *Polygonum Hydropiper.*

(9) Cultivated Land and Allotment areas—
Chenopodium polyspermum, *Atriplex patula,* *Galeopsis Ladanum,*
Torilis infesta, *Polygonum maculatum,* *Polygonum amphibium* (land-form).

Flowering Plants left to come on—
Hedera Helix (Sept. 21), *Phragmites communis* (Sept. 15).

Note: Many stray, scanty, and residual forms, growing under close competition with predominant plants, are delayed beyond their normal flowering period, and may be met with in August and September for the first time; this applies particularly to weeds of cultivation in late crops, and to the casuals of waste ground. Such plants have little relation to the ecological flora. Greater interest attaches to the few residual plants which though found freely vegetating, do not apparently now flower in the district.

Myriophyllum, *Hydrocharis,* *Lemna,*
Ceratophyllum, *Pinguicula,* *Spirodela.*

VIII. AFTERMATH

Although the season may appear to run out in the last days of August, the working year does not come to an end without presenting further phenomena of interest. Failing sunlight and falling temperature become obvious towards the end of the month; and at any time after the middle of August a spell of rain and storm indicates that high summer has gone—the evenings are chill; the night-temperature falls below 40°, and a fire is appreciated. Athough, so long as the days are fine and clear, the midday sun is still powerful, and some of the hottest days of the year (max. temp. over 80° F.) may occur in early September. Yet everything is clearly on the down-grade. Hours of possible sunshine have dropped to 13½ by Sept. 1, and are less than 12 at the end of the month—and here it must be noted that with a lower sun it is the best working hours of the day that are curtailed, and the shadows are always long. The maximum record is usually not more than 11–12 in the first week, and the daily average is only 4–5 (4·7) hours per day. The mean maximum temperature continues high (to 65°),[1] though falling rapidly during the month, with possible maximum

[1] Radcliffe Observatory Reports, lii, p. 107.

of over 80° in the shade, and in the sun 130°.[1] The minimum drops below freezing point by night, usually in early September, and even occasionally at the end of August (1920); the record outside the town (Littlemore) being often 2–3 degrees less than in the sheltered grounds of the Radcliffe Observatory.[2] Light is falling off in quality as well as in quantity more rapidly than the temperature, and the mean temperature of the water reduces to that of the air at 56°. All soil-temperatures begin to show a distinct and steady fall: surface-layers cool off more quickly, deeper layers show a lag; but fo rSeptember the average monthly temperature at depths of 5 ft. is very uniformly about 58° F.[3]

These conditions of temperature, combined with the usual range of rainfall at 2 in. per month, promote a temperate climate, very similar to that obtaining in the early Spring months (May), differing mainly in the fact that the latter was on the curve of rapidly-rising light-intensity, while the present month is on the falling side. All absorptive mechanism, at any rate below the surface-foot, should be still at its best: failure so far is solely an effect of restricted hours of daylight and air-temperature; more particularly as expressed in the longer and cooler nights, with correspondingly diminished rate of recovery in the morning, as the hours of practical darkness now definitely exceed those of working daylight.[4]

Though vegetation as a whole is distinctly on the down-grade, and the season so far over, the reappearance of many conditions of an early Spring climate suggests the possibility of a return to a type of vegetation characteristic, if not of that of early Spring, at any rate of that of the earlier summer. The occurrence of renewed growth among grasses and associated pasture-vegetation, with the possibility of a second crop of Hay, admits the use of the expression *Aftermath* for this period—often the pleasantest time of the year, without extreme summer heat or dust. Bright cool mornings and early evenings (disguised at present by 'summer-time') compensate any effect of intense heat in the middle of the day. Hence in fine Septembers summer may appear extended for a second growing-season to mid-October (1921); just as in other extreme cases October conditions may prevail in August (1922–4), and early frosts may do much damage (as to Kidney Beans, Tomatoes, and Marrows) before the end of the latter month. Technically the season may be still considered as the last phase of summer ('Summer end'), as Autumn does not begin officially until late September (Sept. 23).[5]

[1] Sept. 11, 1919, max. 85·8°; Oct. 5, 1921, max. 80·9°. Sun maximum, 136·7°, Sept. 6, 1920; 131·4°, Sept. 8, 1921.

[2] Radcliffe Record, Aug. 26, 1923, on grass 32.7°; a distinct frost outside the town-area. Local snap-frosts may injure potatoes and garden plants as *Tropaeolum*, *Begonia*.

[3] Radcliffe Reports, lii, p. 120: loc. cit. liv, ii, p. 35, at 3 ft. 6 in. depth the September temperature is that of June and July.

[4] All high-grade flowering plants are of tropical origin, since evolution must proceed at a greater rate where temperature is higher, and this implies a response over hundreds of millions of years to days and nights of fairly equal lengths of 12 (11–13) hours. That is to say, in any extra-tropical migration, plants may profitably enjoy an extension of the working day, time being more significant than intensity of insolation; but they have little power of enduring a longer night, during the hours of which they can only live by metabolizing at the expense of material synthesized during the day. Hence it seems probable that as soon as the hours of darkness overbalance the normal 12, all plant-life tends to close down.

Much the same applies to the case of actively metabolizing animal life, as seen in the migration of summer-breeding birds in August, and the approach of more northern birds flying before the Arctic night. The problem of the ratio of hours of darkness and light is commonly neglected by town-dwellers who sleep indifferently on a fixed time-schedule.

[5] Locally and socially the end of the summer is even more clearly marked by the holding of St. Giles's Fair on the two days following the first Sunday after St. Giles's day (latest Sept. 8, 9) in the roadway adjoining St. Giles's Church. This is interesting as one of the last survivals of carnival nature of the pleasure fair of the lower orders, and the lineal successor of post-harvest fairs of olden

Although the Wheat Harvest may be quite finished before the end of July (1921), or more usually by mid-August—only extending into the first or second week of September in exceptionally late seasons (1922–4)—the the late September moon (full near the September equinox) is called the Harvest Moon. Allowing for the change of calendar of practically a fortnight, this covers the Harvest-period of all cereals,[1] and local Harvest Festivals are held from Sept. 7 to Oct. 15; often not until the first frosts have compelled a final ingathering of vegetables—modern custom including with the kindly fruits of the earth, large Marrows, Tomatoes, and the Potato-crop, as the alien productions of more tropical regions, involving greater photosynthetic activity, but not withstanding early spring frosts, and hence planted late to mature at the end of the season. In a suburban area such crops are now more familiar than home-grown wheat, and a small sheaf may be exhibited as a vestigial curiosity.

The aftermath period is of special biological interest from its mingling of seasonal effects. In late seasons the Harvest is still incomplete. Spring-sown oats and barley may be still uncut, and only gathered in on hill-slopes by the end of the month. Hay is still being cut and carried as the second crop on alluvial ground and higher pastures, or even a late collection of a primary crop. Fruits rather than blossoms are the conspicuous feature of woodland and hedges. Residual flowers of hot summer mingle in great variety with a second crop of early summer and even spring types which begin to flower before winter cold sets in (*Primula*, *Viola*). The weed-flora of allotments and neglected root-crops is at its maximum; Chenopods and Polygonums are now particularly dominant in both variety and number of individuals. The flora is thus more mixed in variety than at any other time of the year, and summer-sown aliens and adventives are often conspicuous as they are casual. On the other hand few of the flowers now out will mature seed; insect-life is also rapidly diminishing; swallows disappear and summer-migrant birds follow; everything is on the down-grade. The last flowers come out and soon fade, but are not renewed; water-plants die off in the over-water parts; leaves come off the trees in increasing numbers; autumnal tints become increasingly predominant; and every week makes a distinct advance in the diminution and collapse of active plant-life. Still in spells of bright sunshine, the final onset of winter may be long delayed, and the aftermath-period may be extended over 6–10 weeks; even well into November (1921).

The summer period does not immediately run out at the first onset of cold and storm. Recurrent warm periods, and even minor 'heat-waves' (temp. over 70°) may delay the final result; and as in the case of the Spring recovery, the oscillation-period is long drawn out and frosts are casual A short period of warmth about mid-October is commonly indicated as 'St. Luke's

times; the only period in the year when the agricultural labouring classes had money to burn[2]; it is also entitled to recognition as a time of family reunion following the same financial inflation succeeding harvest, and is thus vestigial from the oldest post-harvest fair which originally gave Oxford its first significance as a market and social centre. Records of similar fairs are said to extend to the twelfth century. The essential connection of such an institution with the botanical aspect of the ingathering of the crops in late August is now as lost to sight as is that of the return of the scattered members of the University in mid-October with the first fall of the leaf. After St. Giles's Fair the summer is clearly over; young people go back to school again, their elders careful of their health begin domestic fires, autumnal tints appear in the foliage, the first frosts damage garden crops, and nothing is left but to await the fall and the final dissolution of the summer flora; though these effects may not be insistent for another month, and fires begin officially on Oct. 1.

[1] Oats still out in shock, Oct. 1, 1922 (Horspath): Barley carrying on III Terrace, Oct. 1, 1923.

[2] Within living memory 'Harvest Money' to the extent of 30*s.* was paid to labourers working overtime 'as might be required' for the duration of both Hay and Corn Harvest. At the present time 30*s.* is considered as an ideal minimum wage for the agricultural labourer for a week of eight-hour days; till recently 25*s.* a week, and 9*s.* also within living memory.

11. Old River, Medley; *Sparganium* and Villarsia; Aug. 17, 1921.

12. *Limnanthemum nymphaeoides*; Port Meadow, Aug. 11, 1923.

little summer' (Oct. 18), and a few fine days may be equally associated with Martinmas (Nov. 11). A spell of fine and sunny weather in early October, when the autumnal tinting is at an optimum, may be hailed as an 'Indian Summer', on the lines of the characteristic climate of the Eastern States of N. America (1920). Again, as in the case of the Spring revival of bright-coloured flowers, the inherent imitativeness of a race, to whom for untold ages protective coloration was one of the first necessities of life, is shown on the part of the more decorative members of the community in the appearance of sober autumn tints in the autumnal fashion scheme, and even members of the University are expected to affect a 'subfusc' habit.

Little change is so far noted in the leafy canopy of High Forest, though the Bracken is beginning to turn brown. The only trees left to flower are the Cedars (*C. Libani*, *C. Deodara*) and the indigenous Ivy (*Hedera*), which retain their periodicity from the mild winter of the mountain flora of the far East (Himalya). Thus *Cedrus Libani* may produce functional staminate catkins freely and conspicuously in mid-September;[1] while the Ivy begins to flower, extending on into late autumn in sheltered situations, and lasting into the dark days of November.[2] Fruiting stages are more predominant. Acorns, Beech-nuts, *Castanea*, *Aesculus* and *Platanus* burrs are conspicuous, with Hazel-nut clusters and bunches of samaras on Ash, Sycamore, and Maples, the more so in fruiting years (1922). Coloured fruits and berries become conspicuous in the underwood—yellow crabs, purple-black bunches of Elderberries, red berries of the Guelder Rose, and crimson and black *V. Lantana*, purple-pink Spindle tree, white Snowberry, blue Sloes, green Hops, red Hawthorn, scarlet Rose-hips and black Dog-wood, Privet and Buckthorn. The Blackberry crop is at its optimum, and with red berries of *Tamus*, *Bryonia*, and *Solanum Dulcamara*, these decorate the hedges until the leaves begin to fall.

The flowers of herbaceous woodland undergrowth continue as merest scanty relics, with delayed shade-grasses—

Epilobium angustifolium,	*Teucrium Scorodonia*,	*Festuca gigantea*,
Hypericum hirsutum,	*Circaea Lutetiana*,	*Brachypodium sylvaticum*,
Hieracium vulgatum,	*Campanula Trachelium*,	*Aira caespitosa*.

In open clearings, replanted and regenerating forest-plots, a considerable wealth of flowers may reappear. The floral display is not dominated by any particular type; but the variety of forms met with may be still considerable (60 sp.); the collection being the more interesting as it may include with representatives of the more xerophytic summer flora, suggestions of early flowering Spring forms, opening before the frost-period which normally delays their growth. The larger growths of summer have mostly fruited out, but strays occur of the commoner forms of Thistle (*Carduus*, *Cirsium*), *Rumex*, *Epilobium*, and *Arctium*, as also—

Heracleum Sphondylium,	*Pastinaca sativa*,	*Dipsacus sylvestris*,
Senecio Jacobaea,	*Inula Conyza*,	*Teucrium Scorodonia*,

with relics of heathy waste—

Calluna vulgaris,	*Serratula tinctoria*,	*Calamagrostis epigeios*,

and more typical ground-flora of later summer—

Erythraea Centaurium,	*Scabiosa succisa*,	*Agrimonia Eupatoria*,
Clinopodium vulgare,	*Stachys Betonica*,	*Hypericum perforatum*,

[1] Sept. 20, 1921; Oct. 21, 1922. *C. Deodara* (♂) shedding pollen Oct. 22, 1921; Nov. 1, 1924; but in later seasons (1922) dropped half-grown in November after frost.

[2] Sept. 1st week, 1921; Sept. 24, 1922. The rapid fall of air-temperatures occasions delay; many plants expand flower of T umbel only at the end of October, with optimum flowering in early November, the last strays extending into the first week of December.

mingling with miscellaneous hardy forms, which have continued to bloom throughout the season, or have been temporarily checked by drought—

Potentilla Tormentilla,	*Myosotis arvensis,*	*Senecio sylvatica,*
Prunella vulgaris,	*Hypericum humifusum,*	*Rumex Acetosella,*
Epilobium montanum,	*Lysimachia Nummularia,*	*Malva moschata,*
Holcus lanatus,	*Holcus mollis,*	*Agrostis vulgaris,*

appear casual representatives of an earlier season—

Viola Riviniana,	*Veronica officinalis,*	*Ranunculus repens,*
Potentilla Fragrariastrum,	*Fragraria vesca,*	*Lamium album,*
Lychnis dioica,	*Geranium Robertianum,*	*Poa trivialis,*

and occasional—

Primula vulgaris,	*Ajuga reptans,*	*Mercurialis perennis*;

even *Anemone nemorosa* (Oct. 16, 1922); but no sign of flowers of Sanicle, Celandine, *Scilla*, *Orchis*, *Listera*, *Tussilago*, *Euphorbia amygdaloides*, *Lamium Galeobdolon*, *Anthoxanthum*, or *Briza media*.

Many of these forms may reappear in damp hedgerows, together with the relics of summer vegetation—

Sison Amomum,	*Torilis Anthriscus,*	*Pulicaria dysenterica,*
Calystegia sepium,	*Solanum Dulcamara,*	*Humulus Lupulus,*
Pimpinella magna,	*Geranium pyrenaicum,*	*Epilobium hirsutum,*

to mid-October, though flowers become increasingly scanty in hedges and along roadside waste: in cold wet seasons (1924) flowering stages may be as defective in mid-September.

The second-flowering of more woody plants may attract attention, and follows (α) the late-blossoming of delayed buds of the current season, or (β), more exceptionally, as the apparently hastened development of buds which should normally flower in the succeeding spring. In this latter case the buds are developed at their normal period, but the state of perennation is not completely attained, with the result that the flowers grow on apparently precociously when the weather is mild, or often burst out in wet weather succeeding drought. Examples of the first case (α) are afforded by stray September blossoms of Bramble, *Rosa arvensis* and *Rosa canina* (Sept. 27), which appear remarkable as they may be associated with the ripened fruits of the main crop. Examples of the latter case (β) are met with in the familiar garden examples of the summer-flowering (Aug., Sept.) *Laburnum*, *Wistaria*, and in some seasons (1921) of the Apple and Pear,[1] as garden Roses flower a second crop on secondary ramifications of the year's growth.

Again, in the damp meadows, active growth of the grass is associated with the casual flowering of Buttercups (*Ranunculus acris*, *R. repens*), Daisies and Dandelions, together with their usual associates—

Trifolium pratense,	*Plantago lanceolata,*	*Cerastium vulgatum,*
Veronica Chamaedrys,	*Leontodon hispidus,*	*Hypochaeris radicata,*

mingling with the more characteristic representatives of

(1) Damper alluvium—

Leontodon autumnalis,	*Prunella vulgaris,*	*Centaurea nigra,*
Silaus pratensis,	*Angelica sylvestris,*	*Sanguisorba officinalis,*
Scabiosa succisa,	*Spiraea Ulmaria,*	*Trifolium repens.*

[1] After great drought, in 1921, the Holly flowered (♂, Oct. 23, 1921).

The remarkable case of the Horse-chestnut flowering freely without expanding the new foliage, was described for Berlin (Sept. 16) and for Paris (Sept. 10) conspicuously, and in less degree at Hampton Court, but was not seen at Oxford.

In the wet summer of 1922, *Salix triandra* (♂ and ♀) flowered freely on the shoots of the current year (August): in 1924 full terminal panicles of the Elder on strong hedge-growths, in bloom Sept. 27.

(2) Juncetum—

Achillea Ptarmica, *Pulicaria dysenterica*, *Mentha aquatica*.

(3) Dry sandy and calcareous tracts—

Knautia arvensis, *Chrysanthemum Leucanthemum*, *Daucus Carota*,
Achillea Millefolium, *Convolvulus arvensis*, *Galium verum*,
Lotus corniculatus, *Bartsia Odontites*, *Crepis virens*.

Many grasses of the Hay-crop flower a second time, casually and in small degree—

Alopecurus pratensis, *Dactylis glomerata*, *Bromus mollis*,
Festuca pratensis, *Festuca elatior*, *Lolium perenne*,
Festuca loliacea, *Trisetum flavescens*, *Arrhenatherum avenaceum*,

but other characteristic forms do not reappear—

Anthoxanthum odoratum, *Briza media*, *Rhinanthus Crista-galli*.

Leontodon autumnalis is the last characteristic plant of the lower meadows, tinting them yellow with abundant flowers, and leaving later a brown fog of pappus-heads. *Heracleum Sphondylium*, dwarfed by mowing, often whitens broad areas; as also does *Achillea Millefolium* the drier tracts. Such damp pastures may becomes gay with flowers, but the grasses are practically entirely vegetative. Carices also only remain as intrusive vegetative growth, and *Juncus*-forms where residual are fruiting out (*Juncus glaucus*, *J. lamprocarpus*, *J. acutiflorus*).

Open grazed grass-land on calcareous and sandy soils may long continue floriferous with abundant—

Scabiosa Columbaria, *Thymus Serpyllum*, *Pimpinella Saxifraga*,
Daucus Carota, *Trifolium medium*, *Centaurea Scabiosa*,
Euphrasia officinalis, *Campanula rotundifolium*, *Echium vulgare*,
Hieracium Pilosella, *Thrincia hirta*, *Plantago media*.

The first fields may be mown for a second crop of hay in the last days of August (Aug. 27, 1921), and cutting becomes general in the first week of September; in late seasons lasting to the end of the month (Sept. 25, 1922).[1] The crop is remarkable for the fact that it is green hay, unbleached, consisting often predominantly of the foliage of herbaceous flowering-plants other than grasses, practically no flowering grasses, and often of poor quality by a large admixture of Carices. *Glyceria aquatica* may be cut for bedding as late as November. With the final cutting of these pastures, previously showing a wealth of flowering forms, the Hay-fields are left bare, the growth of larger plants is effectually checked, and such pastures show little change for the six succeeding months.

With the carrying of the second hay-crop in the water-meadows the aftermath period comes to a sudden end. The last fields of oats are cleared by the end of September,[2] and the fields of root-crops alone remain with their full equipment of alien weed-flora, usually the more abundant as the foliage of the maincrop is sparse (Turnips), or has already died down (Potatoes). Fine growths are particularly characteristic of highly manured fields of Mangel, now at their best, with roots 6–9 in. diam. Conspicuous weed-form are—

Sonchus arvensis, *S. oleracea*, *S. asper*.
Chenopodium album, *C. rubrum*, *C. urbicum*, *C. polyspermum*.

[1] The last carried Oct. 1, 1922: Shotover Plain cut for Hay, Sept. 27, 1922, and all one side of Bullingdon Bog, Oct. 3, as also some Iffley alluvium, Oct. 5, for litter rather than hay. With the help of machine-cutting such material is much more readily utilized than formerly; being cut very green. Pixey Mead, first crop, was not all cut Oct. 1, 1924, the brown and wet growth left standing.

[2] Barley and Oats of small holders still in shock, Happy Valley, Oct. 7, 1922: the last Barley raking up Oct. 2, 1924 (Cowley).

Polygonum aviculare, P. Persicaria, P. lapathifolium, P. maculatum, P. Convolvulus, P. amphibium.
Atriplex hastata, A. patula.
Veronica Tournefortii, V. agrestis.
Euphorbia Helioscopia, E. Peplus, E. exigua.

With subsidiary casuals as—

Lamium amplexicaule,	*Trifolium arvense,*	*Papaver Rhoeas,*
Lamium purpureum,	*Plantago major,*	*Stachys arvensis,*
Silene inflata,	*Lychnis vespertina,*	*Linaria minor,*
Galeopsis Ladanum,	*Chrysanthemum segetum,*	*Raphanus Raphanistrum,*
Sinapis arvensis,	*Centaurea Scabiosa,*	*Mentha arvensis,*
Solanum nigrum,	*Viola arvensis,*	*Myosotis collina.*

Weed grasses—

Triticum repens,	*Alopecurus agrestis,*	*Agrostis stolonifera.*

Such fields may long be brillliant yellow with Charlock, or white with Radish. On lighter soils *Chrysanthemum segetum* and Poppies may long remain predominant. Potato-fields in which the crop is being lifted may be gay with scarlet Poppies, Charlock *Chrysanthemum segetum* and Radish, exceeding even neglected Bean-fields in display of weeds. Field-Potatoes are the weediest crop ; though in allotment-areas they may be a cleaning crop when grown in full canopy, and dug early for domestic use. Mangel-fields may be yellow with Charlock till mid-October ; the weed-flora being the richer as a wet summer may have prevented effective destruction of seedlings.

Under favourable conditions the aquatic flora of ditches and the river maintains a considerable degree of development, with little change until the first touch of frost. The main crop of flowers is over, but stray plants and lateral shoots may continue to blossom. The water-side may long be comparatively gay with—

Epilobium hirsutum,	*Spiraea Ulmaria,*	*Lythrum Salicaria,*
Mentha aquatica,	*Pulicaria dysenterica,*	*Calystegia sepium.*

The last blossoms of—
Nuphar, Nymphaea, Lycopus, Scutellaria, Malachium aquaticum, Bidens, Sparganium, Oenanthe fistulosa, Sium latifolium, and *S. angustifolium.*

In swamp-areas—

Angelica sylvestris,	*Eupatorium cannabinum,*	*Vicia Cracca,*
Scabiosa succisa,	*Molinia coerulea,*	*Parnassia palustris.*

The most remarkable feature is the late flowering of the common Reed (*Phragmites communis*) in all damp situations, and especially in damp hedgerows, as a grass of widest sub-tropical distribution, only ready to bloom in this climate in September, and often only at the end of the month (Sept. 15, 1924 ; Sept. 25, 1922).

At the first touch of frost, but also under the action of strong winds, all over-water parts of residual aquatics are rapidly destroyed. *Sagittaria* foliage turns yellow, and *Sparganium* brown, as freely as the Bracken of woodland ; over-water foliage and flowers of *Nymphaea* and *Nuphar* disappear. Expanses of *Oenanthe* and *Villarsia* in the open river become mere masses of decaying material, though last traces of flowers persist. Under-water vegetation continues luxuriant, and streams show dense banks of vegetative *Oenanthe, Ranunculus fluitans,* and Potamogetons (*P. lucens, P. perfoliatus, P. pectinatus,* and on gravel-bottoms *P. flabellatus*). Submerged leaves of *Sagittaria* become brown with silt and Diatoms, while residual masses of green Algae float and cloud the water (Cherwell). With the last of the aquatics, the working period of actually indigenous plants may be said to come to an end, and popular interest in the flora rapidly fizzles out.

13. *Glyceria aquatica* ; Ferry Hinksey, Sept. 13, 1923.

14. *Humulus Lupulus* (♂); Cowley, Aug. 13, 1924.

Phenomena closely paralleling the fate of the more indigenous flora are seen in the abundant production of garden-flowers throughout the same period; and in late September, when fruits are falling freely (Apples, Pears, Plums), and the last Tomatoes, Vegetable Marrows, and Kidney Beans are available; the foliage turning crimson on *Ampelopsis* and Sumach, yellow leaves shedding from Tulip Tree, Fig, *Ailanthus*, *Aesculus*, and *Pavia*; evergreen-trees as Laurustinus and *Arbutus Unedo* beginning to blossom; gardens are still gay with mingled flowers of different seasons. With the more characteristic tall flowering growths of late summer, Dahlias, *Solidago*, *Helianthus annuus*, and *Harpalium rigidum*, *Helenium*, Hollyhocks, Summer Chrysanthemums, Michaelmas Daisies, and Tritomas, are mingled the last of the summer bedding-plants, scarlet Geraniums, Ivy-leaved Pelargoniums, yellow Calceolaria, blue Lobelia, scarlet Salvia, forms of Tagetes, Petunia, Fuchsia, Tropaeolum, *Aster sinensis*, *Pentstemon*, Begonia, Gladiolus, *Montbretia*, *Amaranthus*, &c. The Roses of June produce a second crop of flowers often finer than the first. Residual flowers of early summer appear again, as Pansies, Violas, Wallflowers, *Arabis*, and even Stocks; while the panicles of the Pampas Grass (*Gynerium*) are shot up, even later than those of *Phragmites*, often to be cut down by the frost, and before fully expanded in bloom.[1]

Apart from any question of residual flower-production and the ripening of the season's fruits, the most striking feature of this period is the large amount of vegetative activity in the herbaceous types of woodland and pasture, with the full attainment of the perennating habit, as representing a second great growing-time of the year succeeding summer heat, when herbaceous plants put in their most vigorous vegetative growth in preparation for another flowering season. The great majority of indigenous plants grow best in comparatively cool moist weather; and the frost-period which appears to put an end to their activities, is really of wholly secondary significance, as merely interrupting and delaying the normal succession. Hence plant-life closes down under compulsion during the frost-period, but resumes functional activity as the frosts cease in spring, exactly where it left off in the autumn.

In damp clay woodland the soil is covered with a complete mantle of the foliage of—

Glechoma hederacea,	*Viola Riviniana*,	*Sanicula europaea*,
Prunella vulgaris,	*Lysimachia Nummularia*,	*Fragraria vesca*,
Potentilla Tormentilla,	*Galium saxatile*,	*Veronica officinalis*.

Hedge-bottoms are filled with the adult foliage of spring-flowering forms as—

Anthriscus sylvestris,	*Alliaria officinalis*,	*Ranunculus repens*,
Barbarea vulgaris,	*Chaerophyllum temulum*,	*Lamium album*,

and the radical leaves of Docks and Thistles, the basal rosettes of which (*Carduus lanceolatus*, *C. crispus*, *C. nutans*, *C. acaulis*, *C. eriophorus*) are conspicuous among the grass of pastures. Foliage-shoots of aquatics continue active growth in clear-flowing streams, as banks of submerged vegetation—

Oenanthe fluviatilis,	*Callitriche verna*,	*Ranunculus fluitans*,
Potamogeton flabellatus,	*Elodea canadensis*;	

while *Lemna*, at the surface, remains green until the onset of severe frosts or winter floods.

With the return of cool weather, morning mists and evening fogs, implying greater water-vapour content, and partial saturation of the atmosphere in the vicinity of ground-vegetation in woodland and pasture,

[1] Panicles not fully out, Oct. 20, 1922; pushing from sheath, Sept. 24, 1923. Gardens with all summer growth of herbaceous perennials at a maximum, are commonly spectacular in blossom, and at their optimum to mid-October, a month later than the failure of the indigenous flora.

Fungus growths begin to appear in profusion. The Mushroom[1] season is commonly coincident with the ripening of hedge-fruits (Blackberry crop).[2] Massive Polypori appear on tree-trunks, and large Agaric-forms (*Clitocybe*, *Amanita*, *Coprinus*, *Armillaria mellea*) are conspicuous in the woodland base, together with varied types of Basidiomycete (*Clavaria*, *Cantharellus*, *Craterellus*, *Hydnum*, *Thelephora*), of striking growth-form and colour-effects (*Boletus*, *Lycoperdon*, *Scleroderma*, *Phallus*). The Bracken is only ripening sporangia on open heath-land; in the underwood it dies off conspicuously, before *Lastraea dilatata* and *Aspidium*. The Pteridophyte vegetation practically disappears with the death of the foliage of the Bracken; but the Bryophyte flora recovers, and presents more active growth as the herbage previously covering it begins to die off.

In the Oxford District there are now no woods or wet copses in which fallen trees are left to lie and rot to wet pulp producing myriad Fungi. Fallen trees are tidied away or cut up, even if they do fall accidentally, and woodland of the present day is eminently artificial, with neatly trimmed even ways, both trees and underwood being carefully supervised. Only in forest-plots do old stumps persist for 20 years or more (Bagley Wood), and continue to give crops of Fungi in successive years. Fungi also appear in woodland paths and clearings, as bracken and brambles are eliminated or kept cut back.

It may be noted that while the mycelium of such Fungi, as the somatic portion devoted to nutrition, is eminently subterranean, permeating dead timber or the body of the living host; the visible spore-producing parts are fed at the expense of these invisible tracts. Many Fungi thus present 'fruiting years' to an exaggerated degree; and forms appear eminently casual, being rarely found twice on the same spot or in the same abundance;[3] while owing to changes in the overground vegetation, conditions of growth may be continually altered. Hence this part of the flora still remains in the hands of the collector.

The most reliable forms are those of Oak-stool Coppice, with soil-covering of dead leaves only, or Larch Plots with dense carpet of needles: cf.—*Hypholoma* of stumps, *Daedalea* of oak-stumps, *Bulgaria polymorpha* on trunks left lying, *Agaricus melleus* (*Armillaria*) on Larch-stumps and roots, *Auricularia* of Elders.

As conspicuous 'diseases' of trees, cf.—*Rhytisma* of Sycamore leaves, *Dasyscypha* of Larch bark, Polypori (*Poria*) of *Populus* trunks, *Auricularia* (*Hirneola*) of Elder stems, *Armillaria mellea* of the Larch.

At no time of the year is the plant-life so varied and so interesting, and no month is better suited for getting a general idea of the flora

[1] In the drought of 1921, the Mushroom crop was very poor, owing to the ground being baked hard and cracked: Woodland fungi were similarly scarce and ill-developed, where they had been abundant in 1920. In 1922 the Mushroom season was restricted to a week or so in June, before the hay was cut, following great heat in May; and there was a small crop in Autumn (Sept. 29) following a cool and wet summer. In more normal years (1923), the crop is extended from the end of August to early October. The crop again failed in the unfavourable season of 1924; beyond a small output in July 30, there was no special Autumnal crop, Sept. 10.

Present shop-prices average 1*s.* per lb. for the first, ranging from 1*s.* 4*d.* to 6*d.*; but the supply is casual and never abundant.

[2] Woodland and hedgerows are exploited for Blackberries and Hazel Nuts, especially by the juvenile population. The finest fruits are given by *R. fruticosus*, *glandulosus* forms, and by strong growths of *R. Radula*, *R. rhamnifolius*, on Plateau Gravel and Greensand. The common hedgerow form of clay areas (*R. leucostachys*) yields comparatively poor-flavoured and hard fruits, the main crop only beginning to ripen in the fourth week of September. Fruits on higher, better drained formations (Bagley Plateau Gravel, Picket's Heath, Boar's Hill, Wytham, Horspath) ripen earlier at the end of August, and are on sale well into October.

A penny a pound (now 2*d.*, 3*d.*) was paid formerly for picking. Present shop-prices range from 6*d.* to 5–4*d.* per pound. The last on sale Nov. 8, 1923.

Hazel nuts in limited supply are sold at 1*s.*–6*d.* per pound.

Optimists still go blackberrying in Marston Fields.

[3] In Oak-stool Coppice (Bagley) *Clitocybe* was abundant, 1920; *Hydnum repandum* (1921); *Craterellus* (1922), though scanty or wanting in other years.

of the district as a whole. On the other hand, with the closing of the aftermath period, flowering stages are no longer attractive, and little special interest attaches to such reproductive structures when no longer effective. Botanical considerations pass on to the discussion of the relation of the vegetative soma to the increasingly insistent problem of perennation over the darkness and cold of the winter months.

IX. AUTUMNAL TINTS

Early in September the approaching end of the season begins to be made definitely manifest by changes of colour in the foliage of deciduous trees; the uniform mantle of dull green becoming relieved by yellow, brown, and crimson tints affecting whole trees, or at first only isolated branches. The phenomenon is closely related to the approaching death of the foliage, and the leaves of deciduous trees die off *en masse* just as they all broke out fairly simultaneously from the buds in spring.

The change of tint is thus the precursor of the more remarkable phenomena of leaf-fall, and is in this case the expression of the incipient decay and death of the photosynthetic tissues.[1] The greens of the chlorophyll pigment-complex decompose, fail, and are not further elaborated; and with the loss of the green coloration yellow carotins and xanthophylls become increasingly prominent, or may be produced in large quantity. Purple anthocyans of the cell-sap may be similarly exaggerated; or, again, with total loss of cell-pigments leaves pale out, or they may die with a certain amount of chlorophyll still present. Ultimate oxidation of tannin derivatives gives brown tints, and these with yellow carotins and crimson acid-anthocyans afford a wide range of colour-effects which may be blended in the tissue of a single leaf, or characterize different leaves of the same tree, at the same time, or in succession.

Similar colour-changes in the green rind of succulent fruit-structures and berries give rise to the brilliant colour-effects of conspicuous fruits, commonly described as a phenomenon of 'ripening', as expressing what is really a phase of incipient decay, implying the approaching death of the tissues, and preceding their rapid decomposition. The change of colour in the leaves often runs parallel with the change of colour in the fruits as indicating a stage preliminary to ultimate shedding—the latter again a phenomenon commonly involving a special abscission-layer, and the general problem of the removal of effete structures which would waste available supplies of the diminishing transpiration-current.

On the other hand, the case of the coloured fruit runs on lines somewhat different from that of the coloured leaf; since the pigments of the former may be increasingly specialized or localized in connexion with the dispersal of the seeds, as such colours become attractive to food-seeking birds and animals. No such secondary utilization of the colour-changes or chlorophyll failure is seen in the autumnal tints of foliage-leaves; though similar variegation and anthocyan-production in the case of artificially selected sports may appeal in their decorative aspect to horticulturalists.[2]

After a summer season of monotonous green vegetation a change to red or yellow masses of foliage attracts attention as a picturesque novelty, just as after a monotony of blue sky one attaches an exaggerated aesthetic value

[1] Cf. Wheldale (1916), Anthocyan-pigments of Plants, p. 22; Physiology, p. 126; in many tropical trees anthocyan colour-effects may be spectacular in the young foliage: in this country a bronze effect is given only by planted *Ailanthus glandulosa*.

For abnormal production of anthocyan in case of mechanical injury, fungus-attack, cold, drought, and especially in arctic and alpine vegetation, cf. Wheldale (loc. cit.), pp. 24–26.

[2] Cf. Copper Beech, *Prunus Pissardii*, variegated Maples, *Aucuba japonica*.

to tints of pink or pea-green as seen in the afterglow of sunset. In the case of autumnal vegetation the effect on the landscape is enhanced by the fact that different species of tree respond in different ways and at different times, adding variegation and continual change to the countryside week by week; while the individual range within the species is also considerable.

Such colour-changes commonly begin to appear in the first week of September; though, exceptionally, similar death-effects may obtain in late August (1922), and in the case of extreme drought (1921) leaves may fail, turn yellow in quantity, and be shed in great numbers even in mid-July (*Tilia*, Elm, Poplar, Willow). The first indication is commonly afforded by the brilliant scarlet of stray trails of the Virginian Creepers (*Ampelopsis hederacea* and *A. Veitchii*) of garden-cultivation, on exposed walls or chimneys; but the effect is rapidly exaggerated by any extreme conditions which hasten the failure of the photosynthetic mechanism. Following a drop to freezing-point overnight, for a day or two, the *Ampelopsis* turns red *en masse*, and other exotic trees follow suit. As such frosty nights are general in mid-September this appears as a causal factor; but much the same result may be produced by the desiccation of a strong wind at normal temperature; and a gale will produce as great an effect in 24 hours as may a week of more even conditions,—whole trees turning colour overnight and the landscape of thorn-hedges, Elms and Limes showing a distinct change of tint. A certain range may be observed in trees under such conditions. Frost immediately affects exotic types as *Aesculus*, *Liriodendron*, *Ginkgo*, *Ampelopsis*, *Vitis*, *Rhus*; but these are less affected than indigenous forms by wind which turns the xerophytic Hawthorn golden-brown, and brings down showers of yellow leaves from *Populus serotina*. Rosaceous trees as Apple, Pear, Plum are affected by wind as much as by frost. The combined effect of strong cold and dry NE. winds rapidly completes the change and hastens leaf-fall.

While all extreme conditions hasten the change, exceptionally mild weather slows it down, and the period of greatest colour-effect is lengthened by any factors which imply a reduced rate of metabolism,—as cool days with mild nights and dank morning mists, tending to a saturated atmosphere which restricts transpiration and increases the duration of the moribund period. Under these conditions trees may turn colour as a whole and maintain brilliant tints for a week or fortnight,—the weakest trees turning first, the most vigorous and best supplied with water last—and extend the period of autumnal tints for a month to mid-October. In the exceptionally fine warm autumn of 1921, the most spectacular effect was not noticed until the first days of November.

On the other hand, with persistent fine weather, dry and hot by day (Oct. 1921), the rate of change is accelerated, with the curious result that spectacular coloration is reduced; the trees continue predominantly green, though shedding their foliage in quantity and rapidly thinning out. After the preliminary fall of the lowest and smallest leaves, the larger foliage-leaves fade, turn yellow in acropetal series day by day; as soon as they turn yellow, the tips and edges die back brown and shrivel as if touched by a hot iron, and the leaf is cut away in 2–3 days, while those above appear still green and normal. In the course of 2–3 weeks the entire crop may be thus thinned out, and at last one suddenly realizes that all have gone without any real show of autumnal tints at all (good examples in Fig, one of the first to shed, Plums and Pears). Continuous rain may retard the colour-changes by diminishing the effect of excessive transpiration; but the cooling of the atmosphere following rain hastens the process as much as does a strong wind. Alternation of hot days (70° F. or more) in October, with

cold nights touching freezing-point, proves too great a strain for the enfeebled tissues, and also accelerates the effect. It becomes increasingly obvious that it is difficult to isolate the actual bearing of individual factors in the case of trees growing in the open, exposed during such a climatic period to diminishing and varying insolation, cold winds and storm, rain and frost, and a general mingling of accelerating and retarding conditions from day to day.

In the case of the individual tree, leaves change colour in order of development, the smaller and older leaves at the bases of the shoots first, and the lower branches of the tree before the upper. Weaker dying branches with reduced insolation may turn yellow in isolated tracts at any point before the rest of the tree; and these being seen from below and not from the illuminated side, may give an exaggerated idea of their importance.[1] *Ampelopsis Veitchii* possibly affords the most marked, as also the most familiar example, as the plant first bronzes and then turns brilliant crimson-scarlet all over; the uniform mantle of larger leaves of the spur-shoots changing completely, while the delicate trails of summer shoots are still growing and pale green. These last may remain vividly changing when all the larger leaves have been shed to mid-October, and the colour-change may be followed from leaf to leaf up the branch. In warm seasons the Sumach is intensely brilliant for a week, but soon fades out and sheds; often it is merely dull. Rain and gloomy weather complete the destruction of the foliage, and the leaves begin rapidly to fall away.

Considerable latitude is also noticed in the case of individuals of the same species, according to conditions of exposure to wind, &c., or the water-content of the soil. Where growing in close competition, the weaker individuals change first, and strong sheltered specimens may lag two to four weeks behind the others, when the foliage may be killed *in situ* by severe frosts. This individual time-factor, averaging a fortnight, corresponds to what was noticed in the case of the breaking of the buds in Spring and the beginning of flowering-periods, as the indication of a certain amount of biological play in individual variation, which is not easy to separate from ecological response, particularly as the same average period of a fortnight covers the duration of the colour-effect.

A rough distinction may be drawn between conspicuous *Xanthophyll-trees*, turning yellow only; as *Pavia flava*, *Cladrastis*, *Ginkgo*, *Liriodendron*, *Ficus*, *Populus serotina*, *Acer campestre*, and the more brilliant crimson *Anthocyan-trees*,—*Ampelopsis Veitchii*, *A. hederacea*, *Rhus typhina* and species of *Vitis*, particularly *V. Coignettii*, largely cultivated from this decorative standpoint. *Aesculus Hippocastanum* turns golden-yellow with occasional flushes of crimson. Common Elms are often conspicuously golden-yellow. But the majority of indigenous trees show little colour-brilliance. It will be noted that most of the preceding types are plants introduced at a recent or more distant date. Among larger indigenous trees of Woodland, only the Beech turns a golden-brown, which in bright sunshine may glow orange against a blue sky. Minor woodland trees may be more effective,—*Acer campestre* a clear golden-yellow; while the best crimson effects are given by *Viburnum Lantana* and later *V. Opulus*. *Euonymus europaeus* may be bright, and *Cornus sanguinea* dull crimson. The golden-brown of Hedge Hawthorns is often effective against the green Willows.[2] Similar colour-changes are noted in the dying axes of herbaceous types, giving crimson shoots

[1] Cf. the 'golden boughs' of the Common Elm, general in August, and exceptionally in July.

[2] Hawthorns appear more sensitive to drought, Willows to want of light. In 1921 Hawthorns in hedgerows turned brown-yellow while the Willows were still green, in 1922 the Willows yellowed while the Thorns were still green and heavy with red fruit.

to *Lythrum Salicaria*, dull red to Docks, and beautifully tinted leaves to exposed shoots of Brambles on higher sands and gravels.

In all cases it may be noted that brilliant colours are an indication that though photosynthesis may be wanting, the leaves are still alive; this being more obvious in the case of the anthocyan-trees in which the pigment is held osmotically in the cell-sap. As soon as the plasmatic film dies, the cell-contents mingle indiscriminately, and phenomena of general decomposition set in, with the production of tannins and the brown residual colouring matters of the dead leaf. The leaves are normally shed while still living, and these final effects are noted as they lie on the ground. Further, in comparing the distribution of anthocyan in leaves and fruits, the greatest variation is possible; just as anthocyan-pigments may be in excess, inhibited, or left as vestigial traces in the floral mechanism; more especially as such coloration comes within the operation of natural selection through animal agency.

Thus *Aesculus Hippocastanum*, with faint anthocyan-flecks and a colour-change in its older flowers, shows none at all in the fruit-capsule, and only occasional crimson patches on the predominantly yellow foliage. The Elder with intense anthocyan-pigmentation throughout the juicy berries, shows none at all in the white blossom, and in shady underwood fades out until the foliage may appear quite bleached; only in exposed sunny hedges do 'well-ripened' shoots give gold and crimson effects. The Privet, also with pure white flowers, shows a black berry intensely anthocyan-pigmented throughout, yet the leaves are shed green or only darkly bronzed. *Symphoricarpus*, while retaining a pink flower, specializes a snow-white pulpy berry, and also sheds its leaves green. The Holly, with a white flower showing merest traces of residual anthocyan, develops anthocyan only in the epidermis of its intensely scarlet fruit, and the leaves fall away green or only yellow. *Populus serotina*, with abundant anthocyan in the catkins, turns a bright clear yellow before leaf-fall, and the same applies in lesser degree to the Elms, Lombardy Poplars, and Willows. The golden-brown of Lime, Hazel, Birch, and Hornbeam, follow no special anthocyan-effect in flowers or fruit, and the commoner indigenous woodland trees (Oak, Hazel, Ash, Alders) frequently present little colour-change at all. Pine-needles are dead and brown, though the ovulate flowers are conspicuously crimson, the phyllomorphs of *Thuya* conspicuously so before they are cut away, and the dull-greens of evergreen Conifers afford as marked a contrast to the changing tints of the deciduous trees as they did among the bright greens of the Spring recovery. The Bracken may bleach out in shady underwood, but commonly turns brown in the open, often brilliant at the first touch of frost with occasional dashes of crimson, and again affording a marked contrast to the more persistent green foliage of *Lastraea* and *Aspidium Filix-Mas*. Aquatics die off brown in similar fashion (*Sparganium*) with no special colour-effect; *Sagittaria*, with purple-spotted perianth, alone giving conspicuous yellow subaerial leaves.

By the Equinox (Sept. 23) all such autumnal changes are normally much in evidence; the first effects of autumnal tints and leaf-fall being rapidly exaggerated by gales and rainstorms usual at this date, and popularly known as 'equinoctial gales'; though in exceptional seasons (1921) there may be continuous fine weather and no trace of storm. At this time *Ampelopsis* may be brilliantly crimson on exposed walls; in garden-cultivation Pears show crimson and bronzed branches; *Liriodendron*, *Ficus*, turning yellow, to a less degree Laburnums and *Gymnocladus*; *Pavia flava* is already bright orange. Gardens and streets show autumnal wreckage of drifting leaves of the thinning crops; Limes are yellowing fast, and yellow patches appear on Elms, Planes and Poplars. In the Woodland, the first yellow patches fleck some Oaks and Beech: Sycamore and Ash leaves yellow slightly or shrivel up. Yellow leaves and boughs appear on Birch, *Acer campestre*, Willow

(*Salix alba*). *Euonymus* and *Cornus* in the underwood turn purple, and the foliage of *Viburnum Opulus* may be as bright a crimson as the berries. Hedgerows show some Thorns already orange and dull-red, with similar flushes on Elder-shoots, and trails of *Calystegia* conspicuously yellow. So far, however, the effect is not general. In all cases some trees turn casually, while others remain wholly green; free exposure to sun and wind, scanty water-supply, and local conditions of close competition appear as contributory factors. In the case of isolated individuals one side may be bright-coloured while the other is wholly green.

As the leaves attain their optimum coloration they are readily detached. Hence the culmination of the autumnal tints is rapidly followed by the fall of the leaf. Trees coloured *en masse* may be stripped by frost or gale within the week, or continue shedding slowly for a month. The commoner forms may be roughly graded as:—

(1) The first show of September coloration in the case of exotic garden-trees and shrubs, largely cultivated to this decorative end,—*Ampelopsis*, *Rhus typhina*, *Pavia flava*, *Liriodendron*, *Vitis* (forms).

(2) The main crop of planted trees, non-indigenous forms, as conspicuous in gardens, parks, and roads, turning in mid-September and at an optimum in mid-October; more particularly *Tilia vulgaris*, to a less extent *Ailanthus*, *Ginkgo*, *Laburnum*, individual fruit-trees, Pear and Plum; similarly, planted forms of the countryside, Hornbeam, Poplars (Black Italian and Grey), Silver Birch, *Salix alba*, and lesser trees of more open woodland—*Viburnum*, *Cornus*, *Euonymus*, Elder, and Hedge-Hawthorn.

(3) The larger indigenous trees of high forest canopy, conspicuously late, only beginning to change in mid-October, and extending into mid-November,—Beech, Oak, Ash, with Common Elms, *Ulmus montana*, the main mass of Thorns, and *Acer campestre*.

It also appears that colour-effects are largely controlled by physical factors of soil and situation. Thus the Elder only attains characteristic claret-purple on exposed Calcareous Grit, and the Hornbeam a beautiful golden orange. The Beech only gives optimum coloration on Coral Rag. Sycamore and Horse-chestnut are shrivelled by drought, and stripped by high winds and early frosts; but in sheltered situations and on drained calcareous soils they present brilliant orange effects. Elms on Terrace Gravel give a better yellow; on cold retentive clay soils all these may be long wholly green, only colouring in mid-November, a few days before their final clearance.

The same effects follow desiccation and insolation of a hot summer, on well-drained calcareous soils. Thus following the cold wet summer of 1922, autumnal tints were conspicuously poor; as following the drought of 1921 the colour-effects were spectacularly brilliant, and the optimum effect was continued well into November (2nd week).

In suburban areas the spectacular effect as seen at the beginning of the University Term in mid-October, is due more particularly to the brilliant crimsons of the *Ampelopsis*, in general cultivation on house-walls, and the orange-yellow of planted Limes in the streets, together with orange effects on Horse-chestnut and Silver Birch. The main mass of indigenous trees remain green and add to the variegated display.

By the first of November, in the more sheltered valley-area, *Ampelopsis* and Limes are stripped, as also most Birch and tall Lombardy Poplars, *Aesculus*, Sycamore, Plum; most orchard-trees are more or less cleared, and much of the minor tree-growth is already bare. The main colour-effect is now due to the orange-yellow of the Beech, russet-brown of the Oak, clear yellow of *Populus serotina* and *Acer campestre*, and the rapidly changing Elms of the hedgerows, culminating in golden-yellow massed foliage. At this time

evergreens begin to stand out in conspicuous contrast, and all deciduous trees, if not yet turned or shed, are distinctly thinned out and faded. The season is distinguished as 'Half-Fall'. Hedge Hawthorns are bronzed, and Willows, if not wholly stripped, yellow-flecked and thinning rapidly. In sheltered stations, strong year's growths of hedge-Elder may be still wholly green and vigorous: on the other hand, on exposed hill-slopes (Shotover), Oak, Beech, Birch, and Ash may be already wholly bare.

The maximum effect on the general landscape is usually noted in the third week of October,[1] but begins to diminish as extreme falls following frost or storm, from the middle of the month, strip the first and more showy trees before the last begin to turn. A considerable amount of latitude may be observed in different years, and data recorded for conspicuous and healthy trees, which can be checked in successive seasons, afford results as interesting as those for flowering-periods. For this purpose isolated specimens in garden-cultivation, park-land, or hedges, are more suitable than trees growing in close canopy; and individuals of the first exotic class are found to be generally more sensitive to varying conditions (especially to early frosts and persistent dull cloudy weather). In this way it is possible to obtain a general idea as to the time required to complete the change, and the range of variation in each case—for more normal seasons (1923), 'Indian Summer' (1920), following August conditions of extreme drought (1921), or cloudy and wet with 5 in. rain (1922): e.g.—

	1920	1921	1922	1923	1924
Ficus carica[2] (type), the first tree to shed large leaves.					
began to yellow . .	Sept. 26.	Sept. 2.	Aug. 24.	Sept. 15.	Sept. 12.
wholly yellow . . .	—	Sept. 20.	Sept. 10.	Oct. 2.	Sept. 28.
completely stripped .	Oct. 13.	Oct. 12.	Sept. 24.	Oct. 11.	Oct. 12.
Pavia flava (B. G. O.), the first tree to give a carpet-fall (brilliant orange tint).					
began to yellow . .	Sept. 11.	Sept. 10.	Sept. 6.	Sept. 15.	Sept. 10.
optimum coloration	Sept. 27.	Oct. 3.	Sept. 20.	Sept. 29.	Oct. 1.
first heavy fall . .	Sept. 28.	Oct. 5.	Sept. 26.	Oct. 3.	Oct. 11.
wholly stripped . .	Oct. 13.	Oct. 14.	Oct. 12.	Oct. 9.	Oct. 15.
Ulmus campestris, Hedgerow Elm: most variable in situation and record.					
showing yellow boughs	—	July 31.	Aug. 10.	—	Aug. 25.
yellowing	Sept. 15.	—	Sept. 6.	Sept. 28.	Oct. 10.
all yellow	Oct. 15.	Nov. 21.	Oct. 20.	Nov. 1.	Oct. 30.
first carpet-fall . .	Nov. 14.	—	Oct. 29.	Nov. 6.	Nov. 2.
completely stripped .	Nov. 20.	Dec. 3.	Nov. 15.	Nov. 29.	Nov. 19.

Common Elms, with Oak and Beech, show most enduring foliage, but are also extremely variable. The change also depends on the health of the tree; hedge-forms which have been much cut become fungus-attacked. A single tree, wholly yellow, among the normal green, was noted (Marston, Sept. 17, 1924). Individuals on Terrace Gravel may be 1–2 weeks in advance of those on clay and alluvium. All coloration is poor and late in clay-areas, and may

[1] For comparison of autumnal coloration effects in Central Europe and Alpine districts, cf. Kerner (Eng. Trans. Kerner and Oliver, vol. i, p. 488, 1894).

[2] The tree noted is a seedling of the wild type, producing gall-flower and staminate inflorescences (*profichi*) in April. These are usually shed in dry seasons at Midsummer, with the stamens still undehisced. In the cool showery summer of 1924, the crop was carried until leaf-fall, the adult anthers shedding pollen Oct. 1. Full yellow coloration only obtains in warm sunny seasons, and the foliage appears more sensitive to frost than lack of light. Fruiting-forms of gardens may remain wholly green when this tree has been stripped.

be largely wanting as the thinning fall proceeds with the leaves still green. Carpet-falls follow frosts. Final clearance takes place by heavy winds and rain. The trees appear most sensitive to frost, and in mild weather leaves remain on until yellow changes to brown.

X. THE FALL OF THE LEAF

With the exception of the Spring recovery of the foliage of deciduous woodland, nothing is more striking in the plant-life of temperate regions than the complementary and equally simultaneous shedding of the entire crop of leaves at the end of the season. So impressive are these phenomena that more than anything else they mark the periods conventionally accepted as 'seasons', as the essential expression of 'Spring' rejuvenescence and Autumn 'Fall' respectively: the phenomena being similarly spaced out over a period of 2–3 months. This, again, sufficiently indicates the intimate relation of the two processes as mutually dependent. With a short working summer-season leaf-members of such vegetation are, as it were, geared to run their course under optimum conditions; and as they are produced at the same time from winter-resting buds, so they fail in approximately equal times, and are shed *en masse* when effete and finished with. But though this may seem a reasonable standpoint, it does not wholly explain why the leaves should be cut away intentionally, rather than be allowed to die on the branches; nor, again, the fact that many plants (trees and shrubs) are 'evergreen', and do not present this seasonal nakedness; the isolation of introduced and planted evergreens among the older indigenous deciduous trees being now the most conspicuous feature of the countryside in the winter months.

From the standpoint that the leaf is the laboratory of the plant, in which a complex mechanism of photosynthesis of carbohydrate, followed by proteid-synthesis and the elaboration of living plasma—or even the continuance of living processes in non-growing tissues—is wholly dependent on the supply of food-salts and water brought by the transpiration-current of the stem, often for a considerable distance (100 ft.) from the absorbing roots in the soil,—the significance of the control and economy of the latter current, itself largely induced by the actively transpiring effect of the aggregate photosynthetic tissue, constitutes one fundamental problem of all land-flora.

All such plasmic mechanism, again, involves considerable accumulation of debris as waste, whether excess carbohydrate, polysaccharide, products of proteid-decomposition, and the innumerable accessory materials of plant-metabolism, which, in order that healthy life-processes may be maintained, require to be constantly removed from the working units. This in fact constitutes the conception of 'health' as deduced from human mechanism, and read backward into simpler organism. But it is clear that in all cases of anabolic failure, from any cause whatsoever,—whether loss of photosynthetic capacity following reduction or loss of light-supply, diminished or excess temperature, loss of food-salt supply by failure of water-absorption or conduction-mechanism, as also failure in translocation of excess material utilized as food or of accumulated waste—there will be a common result, the metabolic units will become clogged, effete, and will ultimately run down. Thus tissue-units and leaves acquire a life-period of their own, and when done with are themselves so much waste which requires to be isolated from the healthy soma. In fact, the provision of a growing-point, which continually builds new photosynthetic members to replace older ones, and which is the most striking peculiarity of a plant-soma,

is so remote from our own heterotrophic and animal perceptions, that one is apt to forget that it implies not only the destruction of the older members, but the provision of some method of getting rid of waste products from the 'permanent meristem' of the apex. These things being a part of the algal inheritance of land-flora are now taken for granted. The leaf may be thus regarded as subject to senile decay, though the tree itself with growing-points and meristems is practically immortal; again illustrating the parallelism between the leaves of trees and the generations of men pointed out by Homer. Isolation of a dead leaf is effected by means of a special tissue-mechanism distinguished as an abscission-layer. In lesser types of land-vegetation little provision is made for the removal of such structures; but with the attainment and maintenance of the arboreal habit, with multitudinous leaf-members, necessity for stringent economy in the mechanism of water-conduction becomes more insistent. Even in Palaeozoic swamps, arboreal Sigillarias and Lepidodendrons, though growing in water, cut off their effete foliage-leaves, leaving the very characteristic scars on which these names are founded. Similar mechanism of leaf-abstriction is continued as a normal part of the equipment of all seed-plants; the characteristic condition of seed-shedding itself being again but a special case of the abscission of a megasporangium, consequent on similar demands for water-conservation on the part of the parent shoot which initiated the seed-stage.

For the establishment of leaf-fall, one may therefore take the case of a tropical tree to which temperature-relations present no special problem, but the desiccation of dry air may induce a xerophytic habit in overground ramifications. All dead parts remaining in continuity, and so involving a certain amount of physical conduction, become a source of loss to the living organism. Older leaves, necessarily shaded by their successors in an erected shoot-system, failing for want of light, are progressively delimited; the plasmic contents katabolizing out and leaving only products of decay, as tannins, calcium oxalate, resins, and colouring matters. Though in some cases dead leaf-bases may remain (as in older Ferns and a few Palms) as a protective investment of the main stem, it is clear that even in a damp forest-undergrowth such refuse will afford a nidus for epiphytes of all description, as also a holdfast for lianas. In the long run the plants which shed all their effete members and so clean themselves, will not only conserve water-supply most efficiently, but will also keep clear of intrusive and smothering competitors.[1] Hence leaf-abscission may be taken as characteristic and effective for all up-grade vegetation; and the absence of such provision in many otherwise highly specialized herbaceous forms, implies that the problem has been met in some other manner, or no longer arises.

Beyond the conditions of such primary forest,[2] in which each leaf has its own life-period, and new members are being continually developed as the older ones die off, the case of the trees of dry deciduous forest[3] responding to seasonal alternation of wet and dry periods, implies the further adjustment of the organism as a whole—the more significant as the seasonal periodicity may be more emphasized—with the result that the foliage leaves tend to be produced at one time of the year rather than continuously, to run their course simultaneously, and so be shed together as the seasons change. In such case the production of the foliage soon runs parallel with climatic periodicity, though the leaves may still persist over one or more periods of drought, and so appear 'evergreen' as they are not shed until they have been replaced by the new crop. To withstand periods of drought leaves require special protective mechanism, and this is bound to interfere with their normal photosynthetic function. Hence in the limit, the idea of an actively functional leaf to persist

[1] Tall smooth-stemmed Dipterocarps of Burmese forest will cut away lower branches as well, to 1 ft. diameter.

[2] Cf. Schimper, Plant-Geography, Eng. Trans. (1903), Tropical Rain Forest, p. 284.

[3] loc. cit., Periodically Dry Tropical Forest, p. 351.

over one favourable season only, becomes the rule, as solving the problem in the best possible way, and by one which admits of ready adaptation to any combination of extreme conditions. In the case of a hot season, desiccation often appears as the effective cause, and periodicity is thus correlated with solution of the water-problem; the trees being leafless throughout the greater part of the dry months. But once such seasonal periodicity is attained, it may be adapted secondarily to many different cases, according to latitudinal and altitudinal range, and the mechanism initiated for a tropical dry season may be utilized to subserve the exigencies of a cold winter. That some trees shed their leaves on the approach of winter, and others do not, among both indigenous and introduced plants is a fact of observation; and it is equally obvious that the introduced plants, whether evergreen or deciduous, maintain their own periodicity with but little change.

In this country, with a mild, prevailingly wet oceanic (Atlantic) climate, the rigour of the continental winter of corresponding latitudes is less insistent. Oxford is fairly central for England, and is thus well within the zone of deciduous trees of the North Temperate. The great bulk of the indigenous arboreal flora is deciduous in Autumn, and the leaves are off the trees for the best part of six months in the year (Nov.–April). Tree-life is thus wholly closed down, to perennate as best it may over six months of winter, or half its total time.

While the mechanism is now largely a matter of inheritance, and has become an integral part of the working equipment of the race, it must have had some beginning. At this time of the world's history the story of the evolution of any given tree, the causes that may have led to its particular periodicity, and the place of its evolution, are matters of pure speculation. But as broader generalizations it appears well warranted to assume that all are migrant from warmer climates, that all originally were tropical lines of evolution, and that most have passed through a period of dry-forest experience in which seasonal periodicity was established. But in the long evolution of modern tree-types, similar climatic changes may have taken place over and over again; the existing forms are but the few and scattered survivors of lost races, each having come its own complex way, and now largely convergent in that they happen to exist side by side under fairly uniform conditions.

Thus, of ancient Gymnosperms, primitively evergreen, with fern-like leaves, *Ginkgo* alone remains, with a reduced fern-frond leaf, but has become deciduous. Of the types with secondary eminently xerophytic needle-leaves *Taxus* is indigenous and evergreen, *Cedrus* of sub-tropical mountain ranges is also evergreen, but *Larix* of the mountains of S. Europe, with similar tufted spur-shoots, has become deciduous, undoubtedly since it acquired the needle-habit; while *Pinus*, which goes farthest north, remains evergreen, though presenting the culminating phases of 'needle' foliage.

The only indigenous evergreen trees are the Conifers (*Pinus sylvestris*, *Taxus*, *Juniperus*); three residual forms—each now monotypic and the last representatives of their respective genera farthest north, none of them now growing wild locally, and thus appearing as strays from a southern botanical district—as are also the Angiospermous *Viscum* (Mistletoe), *Ilex* (Holly), *Hedera* (Ivy), and very doubtful *Buxus*. These again are solitary representatives of their respective families, widely isolated in the Angiosperm series, again as the last strays farthest north, and the Ivy now the only one found growing by natural regeneration. *Viscum*, one of the most reduced types of the Loranthaceae, an essentially tropical family, does not extend to Scotland (unless planted); the Holly of S. Europe will not stand the winters of E. Prussia, and the Ivy from sub-tropical mountain ranges (Himalya to Canary Is.) retains its autumnal flowering-period. To these may be added low bush-forms as *Erica*, *Calluna*, *Ulex*, and *Cytisus Scoparius*, with deteriorated leaves, as the

reduced xerophytic vegetation of dry heath-land; *Ulex* again being rare in N. Scotland, as it is also wanting in the colder parts of Central Europe, while *Erica* does not come within the local area, and *Calluna* is present only in small quantities.

Many evergreens of milder climates have been introduced, and flourish in sheltered situations, e. g., *Prunus Laurocerasus* (Cherry Laurel) growing as a tree in underwood, *Aucuba japonica* and *Euonymus japonicus* in shrubberies, *Viburnum Tinus* and *Laurus nobilis* of S. Europe, *Magnolia grandiflora* and *Garrya* of N. America; as also many evergreen Conifers,—*Cupressus sempervirens* (Medit. region), *Cupressus Lawsoniana*, species of *Thuya* and *Sequoia* from N. America, *Juniperus*, *Pinus* (*P. Strobus*, *P. insignis*, *P. austriaca*, &c.)—so that evergreen trees now constitute a much more conspicuous feature of the landscape, particularly around towns, than the natural conditions of the flora would suggest.

The difference between the evergreen and the deciduous tree is so striking in the winter season and at leaf-fall, and may have such far-reaching consequences in other directions, that one is apt to exaggerate the point which distinguishes them. In the latter the effete leaves are cut away before the new ones come on, leaving the branches bare; but in the former the leaves, though equally seasonal, remain on until after the new ones come, to be shed usually in early summer. Hence a tree on the border-line may readily change either way. For example, *Ligustrum vulgare*, the Common Privet of English woodland, is normally 'deciduous'; but in sheltered underwood and in mild seasons, much of the bronzed foliage may be retained until spring; and the same holds for Brambles of the underwood, which may retain green functional foliage well over the winter. But *Ligustrum japonicum* is grown for garden-hedges, because it is more definitely evergreen, though this again sheds all its leaves in severe seasons. The point is not so much the death of the leaves, as the reason for their premature fall. As in the case of other special biological habits (shrubs, herbaceous perennials, aquatics), the distinction between evergreens and deciduous foliage may be found in individual species of a genus (*Prunus*, *Ligustrum*, *Euonymus*, *Viburnum*, *Quercus*, *Berberis*, *Magnolia*), or may be constant for genera (*Taxus*, *Cupressus*, and deciduous *Larix*), or again whole families may be one or the other. This suggests the distance to which the first origin of the phenomena must be ascribed; some types may be only now attaining the deciduous habit, while others may have retained it from remote geological times, and others again may have oscillated from one to the other over repeated changes.

These considerations serve to draw attention to the fact that the general periodicity of these introduced or migrant trees is little affected by the new environment. For the cause of such periodicity, and the origin of the deciduous habit, one has to look far away from this country, as it involves problems in the distant phylogeny of each race. But at the same time there may be local and contributory factors, as also a certain amount of play in the living organism; which, though they cannot be regarded as the primary cause of the phenomena, may at any rate affect the *time* and the *rate* at which the change of state takes place, and thus incidentally suggest a clue to the past history of the types. Granted that leaves will be cut away as their metabolism is checked and they become effete, and that failure *en masse* as a crop is the expression of simultaneous production in early stages, as an adaptation to seasonal necessities, and now a matter of inheritance—it still remains to consider to what extent conditions of the present environment may be effective as contributory causes, hastening or retarding the process.

Such external factors may be included as (1) The effect of desiccation and drought, involving problems of available water-supply, conduction, and transpiration; (2) The effect of temperature; (3) The relation of light;

each of which may be conceivably in operation independently, or in conjunction with either of the others.

(1) The effect of restricted *water-supply* in depressing metabolic efficiency is sufficiently obvious, in that all plasma requires a considerable supply of water in order to retain its fluid nature; while loss of water-supply also implies loss of essential food-salts for proteid-synthesis. Thus drought appears as a primary source of leaf-failure, which is recognized in the case of xerophytic plants and trees shedding their leaves on the approach of the hot season, though this does not necessarily exhaust all the cases. The case of excessive water scarcely arises; since when in the soil the plant is not compelled to take more water than it requires, and in sub-saturated air the leaf-area will tend to increase rather than diminish, in the attempt to acquire a more effective transpiring mechanism.

(2) The case of *Temperature* alone is, again, quite distinct. Increase of temperature, by increasing the rate of chemical change, undoubtedly assists metabolism; and so far as temperature itself is considered, the effect of a rise should be always beneficial. Tree-life in the Tropics, given other factors, can live up to the highest temperature of the world's surface. But in dry air, or in combination with deficient water-supply, increased temperature implies increased desiccation, and thus becomes a contributory factor in the case of the leaf-fall of trees and shrubs in a hot dry season, again implying xerophytic habit, and affording the determining factor in the case of trees of dry deciduous forest in more tropical areas.

Similarly reduced temperature should act directly as a causal factor in checking the rate of metabolism in a northern or alpine climate, apart from any consideration of water-supply which may remain at an optimum, and ultimately attain a limit in inducing complete perennation.

(3) More significant will be the effect of *Light*, as possibly the all-important factor, suggesting that the fall of the leaf is the normal response to the increasingly rapid diminution of the hours of daylight in late summer; as conversely the rapid increase in spring was the immediate causal factor in the rapid Spring-recovery. That is to say, foliage which has been working at high pressure during the intense insolation and increasing temperature of June, responds to the steady fall in the hours of the working day, the more so as any diminution in the working time implies cutting out the best hours of the day as the sun rises lower at noon. July, it is true, only drops one hour of daylight, but August loses two more, and with three hours of best sunlight knocked off, vegetation is definitely on the down-grade by Sept. 1, when the first autumnal tints usually appear; and by the end of September, when the day and night periods are equalized, another two hours have been lost. Hence after Michaelmas the night is preponderant. To this, want of water-supply, desiccating dry air, and falling temperature, may be minor contributory, but wholly subsidiary factors. Trees may lose leaves under summer drought, but are just as likely to shed in a cold, cloudy and wet summer, in which light fails more effectually.

(4) On the other hand, more definite reduction of temperature to the freezing-point is immediately effective, since frost disorganizes the tissues, aud rapidly hastens all death-effects: the leaves turn colour more quickly, the colour lasts less time, and the leaves are cut off earlier. In extreme cases hard frosts may kill the leaves before the abscission-layer is formed, and the leaves dry on, to be shed only at a later date, as the base of the leaf-stalk is not wholly killed with the lamina. In the same way frost kills the leaves of sub-tropical trees and shrubs which have no seasonal periodicity (*Eucalyptus globulus*, *Buddleia variabilis*). Snow has no causal relation beyond that of frost; though in the long run it may have a subsequent selective action, owing to the effect of accumulated masses breaking down branches or the entire tree. In this way deciduous trees with open branches clear themselves, and withstand snow-fall as a secondary advantage of the process. Conifers with

pyramidal growth and erect main axis may throw off snow laterally, and remain evergreen (*Picea*, *Abies*): the injurious effect of snow is seen markedly in the anomalous fastigiate varieties (*Cupressus*) and evergreen trees retaining a dense head of foliage (*Quercus Ilex*).

All these features are exaggerated in the frozen winters of the North; but the case of the Temperate zone with a mild winter requires to be taken as more characteristic of the English climate; and it may not be easy to isolate the effect of such factors individually, in the case of the miscellaneous collection of migrants from other climes, which make up both the indigenous and the alien flora of Great Britain.

It may be noted that the subject is further complicated by opposing responses to the same biological factor, in that while the autumnal coloration followed by the fall of the leaf is a phenomenon of death and moribund tissues, the actual abscission-mechanism which delimits the leaf is an actively living process involving dividing cell-tissue. Hence any climatic factor increasing the death-effect may only retard the living cells of the absciss-layer; and conversely an increased rate of division in these cells may be associated with reduced death-rate in the lamina. Thus leaves normally fall away as soon as the colour-effects are at their optimum; but the colours may be precocious and the leaves remain on for a long time; while precocity of the absciss-layers may cause them to be shed while still green. Again, the absciss-layer is often a complex adjustment, as in larger compound leaves a subordinate separation line is formed at the base of each pinnule or sub-segment, as well as at the base of the main petiole. In such case normally the distal segments are detached first; but it may happen that the basal absciss-layer is earlier in operation: e.g., in *Aesculus* the palmate leaves are usually cut away in pieces, as are those of *Ampelopsis hederacea*, and the massive petioles fall away separately (cf. also the pinnate foliage of *Gymnocladus canadensis*). Only rarely do the great compound leaves of *Aesculus* (2 ft. or 2 ft. 6 in. long) fall away whole, sliding down with a remarkably impressive effect after early frosts. *Ampelopsis Veitchii* presents the interesting case of detaching the 3-lobed lamina, no longer compound, and leaving broad tracts of creeper with the petioles long persistent.

Few representatives of plants shedding their leaves at the approach of a hot dry season are found in this country; though slight approximations may be indicated by the case of *Ulex*, *Colletia spinosa* (Hort.), *Cytisus Scoparius* and *Daphne Mezereum* (Hort.), the last of which may have shed all its foliage in late July, and be quite bare before the end of August. The first spinous plants become rigidly spinous in hot summer, with practical loss of leaves, and spinous xerophytic shrubs (as *Prunus spinosa* and *Crataegus*) are early affected by summer drought, particularly when growing in hedgerows with feeble water-supply. It is clear that similar effects may be increased by drought associated with great heat, and in such cases early shedding may be expected in exceptional summers when other trees begin to feel the strain (Elm, Lime). Such definitely xerophytic or **Hot weather Shedding** may be marked in July (cf. July 13–20, 1921), dead leaves in quantity being swept up in streets and parks, and similar Heat-falls are general at any time in August during hot spells; but the effect is clearly anomalous, and bears little relation to the main phenomenon of Autumnal leaf-fall, however much it may assist in thinning the leaf-canopy. Usually in August and September the rainfall is amply sufficient for vegetation, the air is not exceptionally dry, nor is the soil becoming chilled so deeply as to check root-action; the water-temperature and that of deep soil, in fact, only attains its maximum at the end of August when the first changes are noted in vegetation.[1]

[1] Radcliffe Observatory Records, li, p. 120, Curve of Soil Temperatures. Aug. 1922, 5½ inches rain, followed by conspicuously early autumnal changes in foliage. Cf. Radcliffe Records, loc. cit.,

That the case of falling temperature produces no marked effect, so long as the destructive action of frost is avoided, is indicated by the prevalence of evergreen trees in the southern Mediterranean Region, sub-tropical, with a mild winter, in which leaves adapted to withstand the xerophytic rigours of the dry summer are amply satisfactory for vegetating in the cool winter. Such evergreen trees grow freely in this country, retaining their evergreen habit (*Quercus Ilex*, *Laurus nobilis*, *Cupressus sempervirens*, *Myrtus*). A mere drop in the temperature, avoiding the frost-limit, merely gives a resting stage of reduced activity, not requiring any special protective measures. As already indicated, the fall of the leaf is the last phase in the deterioration of the metabolic function, which is heralded unmistakably by the autumnal tints of the foliage, a phenomenon normal in mid-September, of which the first traces are usually in evidence by Sept. 1. Nor can the temperature be said to be at this time falling in special degree. As a matter of fact, the average is even higher than that of April and May when the new foliage is growing with greatest activity; e.g. April 46·99°, May 52·46°, September 56·38°, October 49·53°.[1] Similarly, on a warm muggy day in mid-October, with the leaves falling freely, it is difficult to realize that the temperature can have much to do with the general course of the phenomena; cf. Oct. 5, 1921, 80·9° (84° in London), no frost period, Oct. 18, 75·2°.

The first frosts of autumn average very fairly the first nights of the conventional season (Sept. 23), but in recent years the range may be from Aug. 24 to Oct. 24. Clear bright weather may increase the brilliance of autumnal tints, as warm rain and storm soon spoil them; but the response of leaf-fall follows the autumnal colour-change with great reliability, unaffected by minor local variations; the delay, if any, is in the production of the colour-changes, the fall of the leaf only completes the failing sequence. Intermittent spells of warm weather may hasten the process, bringing down the dying leaves in full perfection of colour. The phenomena are extended over a period of several weeks (6–8), and many changes of weather are possible within such a time. The effect observed at any given date is largely the response to conditions obtaining possibly a month previously. Wind and storm by increasing the desiccatory action, or by lowering the temperature of the wet leaf-surfaces, also rapidly accelerate the visible result, and one stormy night may do as much as a week of previously mild weather. Hence the coming of Autumn often appears conspicuously sudden in the early weeks of September.

Phenomena of leaf-fall being primarily a repetition of the mechanism of xerophytic adaptation to failing water-supply, other signs of xerophytic stress may be associated as the leaves fail. With the first leaves to be shed, down come all immature fruits (*Aesculus*, *Castanea*); cladoptosis of weaker branches may be noted (*Populus serotina*,[2] *P. canescens*, *P. pyramidalis*); while even in the case of evergreens (*Holly*, *Viscum*), all effete leaves of the second season not previously shed during dry summer-spells now carpet the ground,[3] as do also the dead phyllomorphs of *Thuya* and *Sequoia gigantea*. Forest-plots under *Pinus Strobus*, *P. Laricio*, *Pseudotsuga* show a clean new carpet of needles.

As soon as the minimum night-temperature falls to the freezing-point,

Daily Record of Soil Temperatures at 6 in. and 3 ft. 6 in. for 1922. The former maximum 65·8° July 28, the latter maximum 58·7° Aug. 1, and 58° to Sept. 13.

[1] Radcliffe Observatory Reports, lii, p. 107, Mean monthly maximum for 70 years. April 55·51°, May 61·80°, Sept. 64·71°, Oct. 56·41. (Mean Temp. for 61 years.)

[2] *Populus serotina* may shed branches 3 ft. long, and over 1 in. diam. at the scar.

[3] Third-year leaves in the case of *Pinus*.

evidence of these phenomena begins to be conspicuous; the sequence of the autumnal-tint mechanism works out, the oldest leaves feel the strain first, and those on the lower branches, or in the more shaded portions of the tree. The less developed members turn colour and are shed first, while the main crop of foliage is still apparently unaffected.

This constitutes the first **Preliminary Fall**, involving the more sensitive trees, and especially those of some more exotic genera, which takes place normally in mid-September. The time of this first fall varies slightly, according to local modifications in the contributory factors of desiccation, reduced temperature, and available insolation, the effects of which may be more emphasized in different years, and again varies for different trees, as also for different individuals of the same species according to station and relative vigour. Thus weaker individuals, and those in more exposed situations, may show marked advance on others; a range of a fortnight between similar trees often marking the difference between specific or generic types. Some trees are again more sensitive to drought, others to cold, and probably others to the effect of reduced light. Data require to be collected in successive seasons for well-grown specimens and the same individuals which may be readily kept under observation. It is, again, only in the first onset of the phenomena that it may be possible to distinguish the effect of separate biological factors. Later in the season all are more or less in operation simultaneously, leading on to the general fall which ends the active life of the year.

The Preliminary Fall which thus comes into line with the general phenomena of Heat-shedding, or such an example as the shedding of Beech bud-scales (May), spent catkins of spring-flowering trees (Beech, Poplar, Birch, Hornbeam), or spent inflorescences of *Tilia* (August), is succeeded by a long period which may be indicated as the **Thinning Fall**, during which older leaves are progressively cut away day after day, never to such an extent as to give a definite carpet on the soil, but enough to litter the ground; commonly swept up in streets and gardens, but covering the woodland base in Oak-coppice with no undergrowth, and thus gradually reducing the density of the head of foliage on the trees. These then appear progressively thinned, letting in the light as seen against the sky, in a manner wholly distinct from the dense masses of June foliage. The Thinning-fall usually proceeds normally to mid-October; and though the earliest exotic trees may shed completely in September, the great mass of woodland foliage is only thinned and yellowing by Oct. 15. Given fine and mild weather the thinning fall appears the *normal case*, and trees are gradually denuded over a period of 6 weeks, with no special spectacular effect, beyond the falling away of the leaves day by day as they attain their optimum autumnal coloration. But usually towards the end of the month stronger factors intervene; the effect of severe frost, a gale of wind and much rain, brings down the leaves in massed quantities which accumulate under the trees as a uniform carpet concealing all undergrowth, and in gardens and streets become a definite nuisance. Limes and Planes of the streets are conspicuously thinned, though Elms as the predominant tree of the countryside and hedgerows are still little affected, and the landscape may be still predominantly green. At this time the first exotic trees (*Ficus*, *Pavia*, *Ailanthus*, *Liriodendron*) may be wholly cleared. *Ampelopsis hederacea* and *A. Veitchii* practically so, as also Sycamore and *Aesculus*, and to a less extent Rosaceous fruit-trees (Apple, Plum, some Pears, *Pyrus Aucuparia*), more especially conspicuous where growing in situations with poor water-supply; though in sheltered gardens they may be much delayed.

15. Woodland Waste; *Epilobium hirsutum*, *Arctium majus*, Nettles, &c.; Kennington, Aug. 14, 1922.

16. Oak Woodland, Winter aspect ; Dead Bracken and Leafy Brambles ; Cow Hall Bottom, Bagley ; March 18, 1924.

The first **Carpet Falls** of the main flora are due about Oct. 15, and are the more spectacular as they involve the Poplars, Limes, Planes, and Willows, *Juglans*, Huntingdon Elms, and *Castanea*, again non-indigenous, but commonly planted as the most familiar human associates. By the third week of October masses of leaves drifted by the wind become general, and the effect is increased by a severe gale or a frost of 10 degrees. The effect of a thaw after a night frost is particularly spectacular, as the entire foliage of a tree may be quietly dropped, without wind, in an hour or so, as the sun shines on it, giving a dense carpet several inches deep beneath the canopy of the branches. This is best seen in gardens and parks where isolated trees grow over grass (*Pavia flava*, *Sophora*, *Ginkgo*), and is interesting as affording a chance of obtaining a rough indication of the aggregate total area of the leaf-laminae.

The third week in October, which marks the beginning of the Michaelmas Term, is definitely correlated with a critical stage in the general closing-down of plant life now definitely ceasing in all its provinces. Garden-flowers give out; though in sheltered stations the last Roses of summer may continue into November (Nov. 5, 1923). Allotment-produce is gathered in, the last Apples and Pears picked, out-door summer Chrysanthemums are gathered. The Kidney-beans, Marrows, and Tomatoes have gone, though Hedge Blackberries may be still on sale (Nov. 3, 1923), and Harvest Festivals are over. Autumnal tints are at their optimum effect in urban areas, though the countryside may still appear green.[1] *Ampelopsis* creepers are brilliantly crimson on the walls of houses, though the earliest to turn may be already stripping. The first trees to turn have also stripped, and the general effect is soon marred by further heavy falls. Planted Limes of the streets and walks are conspicuously golden-brown, and give the first heavy carpet-falls in the roadways. Sycamore, Horse Chestnut, and Mountain Ash in sheltered situations (and on calcareous or sandy soil) give fine colour-effects; though where much exposed they are stripping, and a few may even still be green. Willows are yellowing and rapidly thinning out: Common Elms only beginning to yellow. The Beech begins to turn a rich brown, *Populus serotina* a pale yellow, and the Birches golden-brown. On the other hand, in sheltered situations and hedgerows, many Thorns, Elder, and Clematis may be still wholly green, and in gardens Rambler Roses, *Buddleia* and other exotic shrubs and trees, show little appreciable change (Weigelia, Philadelphus, Lilac, Pink Almond). The Ivy is at its optimum flowering, and Pampas Grass spreading panicles of yet unopened flowers.

Such carpet-falls occur at any time in late October and early November, following frosts, and leading on to the last cumulative effects of the season. Gales and severe cold rapidly put an end to all aftermath production of flowers, destroying much of the berry-crop. Herbaceous vegetation also suffers, overground parts are destroyed, and gardens become a wreck, to be 'tidied up' for the winter, as soon as all the leaves are down.

Nov. 1 may be termed a 'Half Fall'. The majority of trees are thinning rapidly, and many stripped. The latest (Oaks, Beech, and Elm) with half a crop show brown against the grey skies; though much of the Hedgerow Elms on clay soil are still predominantly green, together with Thorns and Elder in sheltered situations, and much foliage persists in sheltered gardens (Weeping Willow, Apple, Lilac, Forsythia, Rambler Roses); the last Roses persist, and late outdoor Chrysanthemums are at their best in all small gardens. The heaviest falls usually occur in the first week of November. Limes, Poplars, and *Ampelopsis* are cleared, and Planes, *Populus serotina*, Ash, Sycamore, and Chestnuts are soon stripped.

[1] More spectacularly brilliant colour-effects are seen on adjacent Chalk areas in the last week of October.

Final **'Clearing Falls'** approximate Nov. 15, following severe frost, cold fog, wind and rain, though occasional mild and bright days may occur between successive gales and depressions throughout the month. The last leaves come down normally before the end of November; only in exceptionally mild seasons do the leaves of Oak, Beech, Elm, Larch, Birch, and Thorn remain, to be frozen on the twigs by severe frosts, or persist casually into the first week of December.

The killing of the last leaves in considerable quantity on the branches by severe frost may be a conspicuous feature in late November (Nov. 28, 1921, Nov. 25, 1923); such residual foliage in woodland being confined to strong shoots of Oak, Coppice Beech, Turkey Oak, Elm, Hornbeam, and Birch in the open, and much Thorn in hedgerows; as also in the case of Apple in orchards, and in gardens Weeping Willow, Clematis, Wistaria, Laburnum, Lilac, Philadelphus, and *Robinia Pseudacacia*. A few forms may endure these first severe frosts, and thaw out (*Robinia*), but succumb to later and long-continued cold in December (Rambler Roses, Forsythia, Tamarisk). In most severe seasons Privet (*Ligustrum japonicum*) and *Euonymus japonicus* have their foliage destroyed.

The general range of dates for the final stripping of forest-trees, following extremes of temperature and weather, may be illustrated by the case of common wayside Elms—

1920. Roadside Elms stripped Nov. 15, in mild weather (min. temp. 46·5°) following heavy gale of 14th.
1921. Maximum shedding Dec. 1, with heavy rain (·42 in.); min. temp. 31·3°.
1922. Mass-shedding as yellow carpet-fall in dense fog, Nov. 13, 14 (min. temp., 20·5°).
1923. Final mass-shedding only after three days continuous white frost, Nov. 25–27 (min. temp. 11·6°).
1924. Heavy final clearing-falls following a sharp frost, Nov. 19, 20.

After the fall of the leaves residual evergreens afford a striking contrast to the bare deciduous trees and shrubs. Bunches of Mistletoe (in gardens) and tree-trunks clad with Ivy, previously unnoticed, stand out conspicuously. Ivy, Yew, and Holly are prominent in woodland. The first, as creeping Ivy (the old *Helix*-form), now dominates the hedge-bottoms. One realizes the importance attached to the few indigenous evergreens in olden time, as the Yew, Ivy, Holly, and Mistletoe of the Christmas season—the Ivy alone abundant and sufficiently useful to be utilized as fodder in time of scarcity and deep snow—and the significance of the early introduction of Box, Laurel, Vinca, and Rosemary; in later times the Cherry Laurel, *Euonymus japonicus* and *Aucuba japonica* of garden-shrubberies.

By the end of the University Term[1] (Dec. 1st week), the normal winter aspect of the country is fully attained, short days getting dark at 4 p.m., prevailingly damp and gloomy, though with clear sunny intervals,[2]—leafless trees, a sodden woodland, bare hedgerows, damp pastures, full river and ditches, clay areas trampled by cattle into deep mire, become characteristic. All plant-life closes down to perennate as best it may over a period of 4–5 months, and popular interest in the local flora evaporates. An urban population, living out of touch with the countryside, deriving food and fuel from shops, with little thought as to where these things come from, regards plant-life from a wholly detached standpoint, often merely from that of decorative value or sentimental curiosity.

[1] The full extension of Autumnal leaf-fall is practically identical with the duration of the Michaelmas Term (8 weeks), as the Christmas Vacation expresses a period of passive perennation, with little variation in average temperature or insolation.

[2] Nov. 1923 holds the record with 108 registered hours of 'bright sunshine' out of a possible 265, or 40 % of daylight (previous next best, Nov. 1896 with 91 hours (Radcliffe Records). The average for the month is 60 only, or $\frac{1}{4}$ of actual daylight, and just $\frac{1}{12}$ of total time.

XI. PERENNATION

With the stripping of the foliage of deciduous woodland all vegetation passes into a condition euphemistically described as 'winter-rest', which is really no more than a period of *passive endurance* of a season with few hours of daylight, feeble sun, a low temperature, possibility of thick damp fog, and subject to the effects of frost, the desiccation of bitter cold dry winds, or burial beneath a mantle of snow, which characterize the winter of the North Temperate Zone. All higher vegetation, except the hardiest much-enduring forms, closes down for a period ranging from 4–6 months; and from mid-November to mid-April there is little doing in the plant-world of this country; the main volume of higher plant-life of woodland vegetation not being fully set going again until May; though cultivation of carefully assisted garden-forms of alien value, grown for decorative flowers or vegetables, may present a deceptive appearance of Spring.

In woodland and hedgerows the overground parts of trees present bare branches with protected buds on the ultimate twigs, the ground is carpeted with dead leaves, dead Bracken, and shabby Brambles. Herbaceous plants of fields and hedges are cut back to the soil level, presenting rosettes, basal shoots, leafy rhizomes, or are restricted to subterranean parts; annuals survive only in the seed-stage. The over-water parts of aquatic vegetation are dead and decomposed, giving a desolate aspect to river-banks and ditches margined with skeletonized pollard Willows. Only the pastures remain predominantly green, with the grass-carpet cut down to a minimum of short shoots. All flowers vanish from fields and hedges, with the exception of casual waifs and half a dozen of the hardiest most enduring plants in sheltered corners, hence recognized as the commonest 'weeds'.

This winter aspect, which runs for practically half the year, is naturally so familiar, and the necessity for such perennation or hibernation on the part of plants appears so obvious to people who have themselves to take special precautions in extra clothing and firing to counteract the inclemency of the weather, that it is often difficult to realize that the plants have no fore-thought in the matter, but must owe this protective mechanism to the rigorous natural selection of distant ages and of possibly quite different environment. Species introduced from warmer countries do not 'adapt' themselves to the new conditions; garden-forms remain 'tender', and the evergreens of S. Europe do not necessarily shed their foliage in our winters. That is to say, the seasonal response on the part of the plants, now presenting a periodicity which fits that of the English climate, has not been evoked by the conditions under which they now live, but is again the inheritance of past ages. In fact there can be little doubt that the present Flora is limited to immigrant types which happen to have been able to solve the perennation problem with equipment already in hand; others have succumbed, have failed to establish themselves, or lead a precarious existence on the verge of extinction; just as newly imported plants are killed by the frost of severe winters, though they may survive in sheltered stations. Admitting that this periodicity antedates the origin of the more localized British Flora, it is interesting to inquire to what it may be really due; and how plants ever came to acquire such a mechanism of seasonal 'rest' or 'perennation' in the first place. The modes of Perennation, again, do not present one constant method of response to the climatic change, but are singularly diverse. The resting stage of a woody tree with winter-buds exposed on the highest branches, 100 ft. or more from the soil-level, is wholly distinct from that of

a herbaceous perennial cut down to a leafy rosette, or from that of plants as the Bracken, of which all overground parts die and decay; and this last, again, is very different from the case of the perennation of an annual weed solely in the form of minute seeds left to chance fate on the soil-surface, or that of an aquatic at the bottom of the river. The subject is clearly one of great complexity, and to obtain fundamental ideas it is necessary to go back to the story of primary woodland in the optimum condition of tropical rain-forest, where trees compete with no trace of winter cold or of any adverse conditions beyond close contact with individuals of the same class. Here it soon becomes apparent that the beginnings of perennation, as of most other special phenomena in land-flora, are to be sought in attempts at the solution of ever-insistent water-problems of vegetation subject to chances of desiccation; the acquisition of some sort of perennation-mechanism being obligatory for all vegetation of the land, to which in no case can a full supply of water be guaranteed indefinitely even in the most favoured locality.

> In the entire range of plant and animal life of this world, there is possibly no more astonishing spectacle than that of a large deciduous tree, as a massive organism, 100 ft. high, and trunk 3–5 ft. diameter, wholly dormant, with sealed bark-covering, and embryonic meristems protected in all end-buds, passively enduring often severe cold, darkness for some $\frac{3}{4}$ of total time, wrecking gales of the winter period, the extreme desiccation of frozen NE. winds, and dependent for renewed growth wholly on reserves of the past season. Such trees pass as the commonplace of this part of the world. Rhizomes and bulbs, root-stocks and seeds, perennating more in the manner of dormant animals and insect-life, secure beneath the soil-surface, in holes and sheltered crannies, strike a more familiar note as following human methods of inhabiting caves and dwellings, implying shelter from wind and rain, with fire to raise the temperature, and living at the expense of food-supplies gained in the previous season. That there will be a limit to such endurance naturally follows, and trees reach this limit farther north, as a smoothed snow-mantle on the ground increases the desiccatory action of frozen winds on all parts exposed above the snow level [1]

In more elementary types of land-flora the problem of resisting desiccation may be simply solved by mere endurance on the part of the entire soma in an air-dry condition; recovery taking place on the restoration of water (many Algae, Fungi, Lichens, Bryophyta, and more rarely in the case of some Ferns). This may serve where there is no special differentiation, but in more elaborate somata co-ordination of complex tissue-systems necessitates a continued full water-content. In the generality of land-flora the asexual spores, of algal ancestry, retain this function of enduring in an air-dry condition; and the problem being solved in this way, the somata are saved the consequences of such extreme measures. Again, in the case of all subaerial organism, with no power of free locomotion, some phase of perennation is essential, in order to subserve a dispersal function by movements of air-currents rather than by water. In the case of Fungi, Bryophyta, and Ferns, spores perform this function, and among Angiosperms the air-dry microspores may still function as wind-dispersed pollen-grains, while the megaspore side of the story has passed on to the evolution of the seed-stage, in which, for a large number of forms, the embryo still achieves the property of becoming practically air-dry, in the older method of the undifferentiated soma. The typical seed, as a structure which may withstand desiccation, more or less, and in extreme cases remain viable for over

[1] Plot (1684), Phil. Trans., p. 759, records the Great Frost of 1682–3, when oak-trees were split, often with a loud report, in many parts of the country. Other trees to suffer similarly were Elm, Ash, and Walnut. Yew and Holly were killed in the open. *Ulex* killed or cut to the ground, as also *Laurus*, Laurustinus, *Arbutus*, *Jasminum officinale*. Much Wheat, where there was no covering of snow, had to be resown.

100 years, and at the same time be carried to a distant station, is the perennation-phase *par excellence* of the higher land-plant; to the extent that somatic persistence becomes in the limit a wholly secondary consideration, as the possibilities of rapid regeneration from the seed-stage increase; though special adaptations for somatic perennation are still utilized in older forms of forest-habit with slower rate of growth and attainment of reproductive maturity.

Thus a tropical forest-tree, itself perennial, may present no specialized perennating structure other than that of its seed-stage, with its chance of dispersal. In the limit this latter highly specialized dispersal phase remains as a wholly satisfactory mode of perennation over all adverse conditions on the part of the *annual* and *ephemeral* type of plant; although it should be sufficiently clear that the seed-stage was never initiated solely for this purpose: but under a new complex of biological factors it has been found satisfactory and successful in the solution of a further problem.

Between these extremes lie the cases of the *deciduous tree* and the *herbaceous perennial.* These again are seen to have originated as the response to the conditions of a hot dry season rather than to winter cold. Even in a tropical rain-forest trees do not all flower and fruit continuously, but present a certain periodicity of their own: some being in flower and fruit at one time, and others at another. The forest presents a continual change, though the biological conditions may appear fairly uniform; this being the effect of climatic variations in past ages; since in no station of the modern world can optimum conditions be supposed to have obtained generally throughout all geological time. Even the best 'primary' forest carries races of very diverse descent, and must be regarded as a mixture of forms, as survivals which have managed to maintain their lead through all the changes and chances of past epochs. In such a primary rain-forest herbaceous perennials and annuals are non-existent, except as they may maintain station as epiphytes perched on the branches in higher forest levels.[1]

Assuming the specialization of deciduous forest in response to seasonal changes of wet and dry seasons, it is evident that with a shortened annual working-period for the foliage-leaves (soon to be killed by the excessive insolation and desiccation of the hot summer) the necessity becomes insistent for some provision for a new crop of leaves which may be quickly produced when conditions again become favourable. Both terminal and axillary buds acquire specialization in development. Chances of survival will be improved by the provision of anything in the way of protective mechanism. The outer leaves of the buds thus commonly acquire a special xeromorphic value; whether as arrested leaf-bases, precocious stipular lobes, anything rather than the highly organized and complex photosynthetic lamina itself—together with further equipment of wax, resin, woolly hairs, or cork-layers in individual cases. Such *perennating buds* become the normal equipment of the leafy twig, to be hastened and elaborated on the vegetative shoot as the working period of the year is the more reduced. Time is required to design and elaborate such cellular constructions; and, in the limit, only those trees survive in which the bud-stages are fully effective at the onset of the dry season.

> By an ingenious arrangement of older types of tree-growth, the evolution of a specialized leaf-member allotted to special photosynthetic work, implying its ultimate death, was associated with the necessity for replacing the member as it became effete. This was solved by the initiation of new growth in the

[1] Schimper, Plant-Geography (Eng. Trans. 1903), p. 290: cf. Wallace (Forests of the Amazon), except along roads and the forest-edge at river-margin, no flowers below 100 ft.

'leaf-axil', at a point at which any food-supplies obtained from the leaf can be most conveniently tapped; while at the same time protection is afforded in the angular space between the leaf-member and the main axis. The elementary biology of this process is still to be traced in many forms of sea-weed, and the method undoubtedly represents a part of the initial equipment of the first arboreal forms of the land (cf. *Chara* to Lepidostrobi). As a limiting case, which becomes in the long run the general rule, the number of such axillary buds normally reduces to the end-term of one only; and an empirical morphological rule has been deduced that every photosynthetic leaf-member may subtend such an axillary bud. In the case of non-photosynthetic members the bud may be wholly suppressed (as in the case of floral structures devoted to functions other than vegetative growth), or it may be retained where requisite food-supply is available from other sources. But it follows that, in its primary relations, the story of the axillary bud is to be traced in the leafy shoots of forest-trees, as representing the primary vegetation of the land.

The essential point to note is that in thus providing for the replacement of an effete leaf-member, the plant-soma does not put in a new leaf, but a new *growing-point*, corresponding in morphological value to the terminal growing-point of the main axis, which has the effect of replacing the dead member by an entirely new shoot-system, with indefinite capacity for making new leaf-members in a corresponding phyllotaxis-construction. This covers the general method of vegetative ramification adopted in higher flowering plants, as now essentially the habit of growth-extension, replacing older methods of dichotomy of the stem-apex. Further specialization may follow in some cases, diminishing the value of such lateral growing-points, giving them the character of 'reduced laterals', or 'spur-shoots'; just as in extreme cases the axillary buds may be partially or wholly suppressed in tracts presenting elaborate morphological growth-forms;[1] as in evergreens, generally, the development of lateral buds may be modified by the fact that the subtending leaves may continue functional over more than one or two seasons.

Where seasonal effects are not insistent, this normal method of shoot-construction continues indefinitely, and a tree in active growth may put in more than one degree of ramification in one season. But a limiting time-factor again intervenes. As the working-period of the year is restricted, so lateral ramification is reduced: more than one degree of ramification in one season being comparatively rare in the case of trees growing in the open.[2]

In the limit somatic ramification is adjusted to one degree per annum; it could scarcely be less, or the plant-axis would cease to branch. But the limiting case, as usual, becomes the general rule for plants on the verge of their distribution. This production of terminal and lateral buds, implying only one degree of ramification each year, is so general in these latitudes that it passes as the normal case, to which a secondary ramification appears as an exception, and the free ramification of a herbaceous perennial, or even of an annual, as being on a distinct morphological horizon.[3]

Cf. (1) Garden Roses flowering in June from shoots of the preceding year, put in a second ramification of the first flowering shoots to bloom in September on such shoots of restricted persistence.

(2) Strong growths of Willows, Poplars, especially after lopping, put in a second ramification (as also *Prunus spinosa*).

(3) More obviously in the Oak, as 'Lammas Shoots', conspicuously developed in regenerating Oak-coppice, and general in the case of the destruction of the first foliage of older trees by *Tortrix* caterpillars.

[1] Cf. specialized Conifers as *Pinus*, *Cedrus*, *Araucaria*, *Cupressus* phyllomorphs, and *Thuya*.

[2] Active ramification of shoots fruiting to the second degree, and vegetative to the third, is seen in the year's growth of *Buddleia variabilis* now general in garden-cultivation (from S. America) with no bud-complications. In the case of the phyllomorphs of *Thuya* and *Cupressus*, branching is continued to the 3rd and 4th degree in the same season, for these special dwarf-shoots, and the spinous shoots of *Ulex* also ramify to the 3rd and 4th degree.

[3] Bot. Mem. 14, p. 38.

In all these cases of tree-growth the effect is entirely secondary, and normal bud-formation begins. The Oak, for example, lays down a cycle or more of bud-scales (stipular), but then changes to the direct production of foliage-leaves and extended internodes which may give growths a foot in length by June 21. The Willow always puts in the single bud-scale (of two stipules), which is early shed, before extending the lateral axes.

Admirable examples are afforded by lopped Horse Chestnut regenerating strong summer-shoots to the second degree with transitional leaf-base scales.

All such Lammas-shoots continue the same wood-system, and the main axis shows but one ring of xylem; just as *Helianthus annuus* will ramify as a summer annual to laterals of the 1st and 2nd degree.

The essential point is that these lateral leaf-members subtend growing-points similar in organization to that of the terminal, and hence normally liable to the same general methods of growth and biological response. In the case of the typical deciduous tree there is great scope for the control and management of these buds—the more so as they have to be prepared for active growth-extension in a shortened growing season. In such case there is every necessity that preparation shall be made at an early date. Hence, even at the first breaking out of the new foliage in spring, provision begins to be made for the further development of the shoot-system, and axillary buds may begin to be visible as soon as the leaves are fully functional. In some cases of special secondary significance, the terminal growing-point of the shoot in older plants may be suppressed, and subsequent ramification is effected solely by the laterals (*Carpinus*, *Ulmus*, *Tilia*).

In the case of the great majority of indigenous trees, the first leaf-primordia formed in these buds (both terminal and lateral) are not photosynthetic members, but reduced structures, of lamina or merely lateral stipular growths, which constitute protective *bud-scales*, and the primordia of foliage-members are laid down only after a certain number of bud-scales have been allowed for; correlated, again, with an elimination of the usual internodal extension between the members. This is done, it will be noted, at the optimum growing-period of the year, without fore-knowledge of change, but is now a part of the inherited equipment of the plant as established by natural selection. The first work, that is to say, of these lateral growing-points is no longer to make new foliage-leaves, but to provide for a perennation-mechanism.

Such axillary and terminal buds begin to be laid down in May, and are commonly well-formed in June; so that there can be no doubt that the primary significance of such buds, following the case of the fall of the leaf, is really the provision of perennation-mechanism over a period of drought, represented by a dry hot summer season, and that the buds of indigenous trees are intended primarily for perennation over a hot summer, rather than over a cold winter. The development of lateral ramification, as also of terminal extension, is now adjusted to the exigencies of seasonal water-supply, and the great majority of trees are fully equipped for winter-perennation at the onset of the hot summer-period. Endurance of dry summer is the primary perennation-problem; but as the trees now retain their foliage over a relatively cool summer and autumn, so the primary perennation-equipment becomes equally effective for protection over the later frost-period.

The **Herbaceous Perennial** follows similar lines of special adaptation to summer drought. In the general case of land-flora, the primary factor in determining unfavourable conditions is always lack of sufficient water-supply; and, as in the preceding case of the deciduous tree, the herbaceous

perennial presents special morphological peculiarities as a parallel response to seasonal periodicity, in which the extreme drought of a hot season is the determining factor—the exhaustion and death of all subaerial shoot-systems implying the necessity for regeneration from *basal buds*, with the consequent elimination of any direct connexion with the vascular system of the previous year's stem, and any necessity for increasing the annual rings of wood.

In such case any provisions against excessive loss of water in the young plant or earlier vegetative condition are equally effective in the case of the young regenerating shoot-system; and thus rosette-forms, prostrate stems, and rhizomes, become the general equipment of such perennials in the vegetative condition, and are equally effective as the perennation-stages of the flowering shoots.

In extreme adaptation, however, the necessity for enduring the desiccation of an unfavourable period of heat-drought in the annual cycle implies a reduction in time of the complementary favourable period intervening before the onset of another unfavourable one, with consequent necessity for rapid development when conditions do become favourable. This again becomes the more insistent as the perennation-period of the year is relatively longer. Hence storage of food-reserves which may be expended in rapid growth-activity introduces a secondary factor, and special organs with food-storage, often below the soil-level, as tubers, corms, bulbs, and even tuberous roots, become the commonplace of hot-season perennation. In the limit, many such structures may endure the desiccation of dry air for some six months in the year or more.[1] Similar storage-organs occur as the general equipment of perennial herbaceous forms, following as the natural consequence of an endurance of periods of heat-induced drought. These special adaptations are, however, of racial or biological origin; their initiation goes back to far distant ages, and may have little apparent reference to their present ecological significance in a modern flora. On migration to more favourable stations, as also on a change to better conditions of water-supply in the same locality, this structural biological equipment, produced as the response to previous climatic conditions, may persist, even when no longer essential; as it may also come in useful for some purpose for which it was never intended.

Thus bulbs of *Scilla* in woodland, or those of *Fritillaria*, at 4 inches deep in alluvial meadows, are not dried out in summer-perennation. The seed in its evolution is essentially a product of hot-season perennation, yet many seeds have now but slender viability in the air-dry condition (Oak, Horse Chestnut, Elm, Willow, Poplar). The rhizome of *Iris Pseudacorus*, now a sub-aquatic, is never dried off in the manner of allied sub-desert forms. Among indigenous flora, many perennating organs remain useful for the subsidiary functions of reserve-storage, although no longer dried out (cf. also tubers of *Ranunculus Ficaria*, rhizome of *Pteris* and *Equisetum*).

A migrant northern flora may thus contain within it representatives of older more southern floras, and a climate in which winter cold is more characteristic has to be negotiated with the equipment gained through drought of a hot summer. On the other hand, the extent to which a tropical plant, however effective its subterranean perennation-mechanism may be, will prove resistant to frost is only solved by experience of such low temperature.[2] Successful endurance of extreme conditions may be thus associated with a physiological factor, beyond the morphological expression of actual

[1] Familiar examples in garden-cultivation are afforded by the case of tuberous Begonias, the root-tubers of Dahlias, the bulbs of *Narcissus* and Hyacinths, the corms of *Crocus* and *Gladiolus*, rhizomes of *Anemone*, &c., which are freely stored in shops or dry cupboards for half the year.

[2] Cf. bulb of Onion, tuber of Potato, rhizome of *Phasaeolus*, all killed by frost, although more or less subterranean.

perennating organs. Examples are also sufficiently familiar in garden-cultivation of plants introduced from warmer climates which tend to retain their ancestral periodicity; only the sieve of natural selection can correct their response, or determine their successful establishment; though artificial assistance of human agency may obscure this action within the historical epoch of a few generations. In this way, another component is added as a time-factor, according to the manner in which the older periodicity is gradually adjusted to the new sequence of climatic changes; though where the latter are less extreme, need for change may not be immediately insistent.

The essential relation of the great variety of phenomena of perennation to summer drought, rather than to winter cold, is conspicuously illustrated by the behaviour of many introduced garden-plants in a mild autumn. Many plants which show extreme adaptations for enduring summer drought come on freely in the vegetative condition as soon as adequate water-supply is regained.

Thus *Daphne Mezereum*, a xerophytic shrub of S. Europe, sheds its leaves from July, and may be bare in hot August, yet may become green and leafy again in a wet September (1924); though losing this foliage again after frost in chill October.

Herbaceous perennials, as Michaelmas-daisies, *Helenium*, Chrysanthemums, send up new basal shoots as the older inflorescence-axes flower out. There is no 'resting-period', but the new shoots remain at their late October value stationary for the succeeding winter months.

The most characteristic bulbous type, *Lilium candidum* of S. Europe, after the hot summer sends up new vegetative leaves in wet August and September. These also remain stationary in the condition attained in early November, until March, with little further change beyond probable damage by severe frosts.

Other forms with subterranean perennating organs, whether rhizomes or bulbs (cf. rhizomatous Iris and Spanish Iris), send up leafy shoots which may be 6 inches above the soil in early November, again to be held stationary until March.

Even annuals germinating from seed perennate with no special adaptation in the seedling condition. This is particularly well seen in long-introduced cereals, as Wheat, Barley, and Oats. These germinate freely in October, and may be 6 inches high by the beginning of November, but also remain stationary at this level until Spring.

In all these cases the new growth is initiated at the expense of reserves stored before the summer drought, and the marking-time period expresses the failure of further photosynthetic development, owing to low temperature, but still more to lack of effective hours of sunlight. The temperature may be, in fact, no better in early Spring, but the rapid rise of light-value induces new and active growth. In all these forms the so-called 'winter-rest' is not a phenomenon of specialized perennation; but merely expresses passive endurance in a wholly unprotected condition—the plants being as it were caught napping by the climate.

The perennation of what passes as the more indigenous herbaceous flora follows the same general rules; and though the onset of new growth is more usually further restricted into later Spring, the methods of perennation are similarly but the expression of a condition of affairs originating in response to hot-season drought, For the better part of six months the flora as a whole is thus marking-time. The great majority of plants are wholly at a standstill, subject to further damage from storm and frost, but making no advance until the Spring. For some six months in the year the working flora may be disregarded and put on one side. It takes up in April exactly where it left off in late October.

It would thus appear that in the northward migration of any such forms liable to be killed by a severe season, the appearance of any delay in the annual periodicity, by which individuals do not begin to vegetate so early in mild seasons, or are delayed more definitely until the rise of temperature is assured, implies that any mutation on these lines will prove advantageous, and should so far stand a better chance of survival, since less prone to damage. Hence such retardation becomes the effective physiological provision against the rigour of the climate, and may be so far regarded as a definite adaptation for successful perennation. Plants with similar biological equipment for drought-perennation may still differ in their degree of physiological adaptation on a time-schedule. Similarly, physiological mutants proving more enduring of frost may be isolated by natural selection, though presenting no morphological alteration that may be visible to the eye. A race on a time-schedule, in which the prize falls to the last competitor rather than the first, is less usual in general phenomena of living competition; but, as in human affairs, the possibility may arise, and the race is not always to the swift. Examples of such success in the isolation of specific forms, as expressed in varying degrees of delay, are found more or less marked in familiar plants—flowering-stages being more easily checked.

Viburnum Tinus of S. Europe, in garden-cultivation, begins to flower in November, but the main crop only comes on in April. *V. Lantana*, indigenous in woodland, shows the terminal corymbs similarly perennating with no protecting bud-scales, but is delayed until May. The case of *Ulex*, flowering sporadically in any winter month, but culminating in March and April, is very similar. Among forms of *Crocus*, the autumnal-flowering *C. speciosus* (Sept., Oct.), *C. sativus* (Sept.), and *C. nudiflorus* (Sept.) may be compared with the spring-flowering *C. aureus* and *C. vernus*. *Galanthus Elwesii* of SE. Europe may flower before Christmas, but *G. nivalis* only in Jan., Feb.; as the Christmas Rose (*Helleborus niger*, Oct.–Jan.) may be compared with *H. orientalis* and *H. foetidus* (Jan.–March).

Introduced trees and shrubs, flowering on the bare twigs—*Daphne Mezereum* (Oct., Nov.–Jan.), *Jasminum nudiflorum* (Oct.–Dec.), *Chimonanthus fragrans* (Jan.)—are paralleled by the Hazel (catkins shedding Jan. 1), Alder (Feb. 1), and the common Elm (March).

As typical Spring flowers blossoming casually in Autumn may be included *Primula vulgaris*,[1] *Viola Riviniana*, *Mercurialis*, and even sporadic *Anemone nemorosa* of the woodland, with Daisies and Dandelions of the pastures, and strays of common Buttercups—*R. repens*, of human association, *R. acris* of artificial pastures—culminating in May; but not the longer indigenous *R. bulbosus*, *R. Ficaria*, and *R. auricomus*. Other woodland forms as *Euphorbia amygdaloides*, *Viola hirta*, *Arum maculatum*, *Orchis mascula*, as also the Cowslip and *Tussilago*, do not flower casually in autumn; though one would not be very surprised to see them do so. Garden-forms, less definitely delayed, are valued by florists as being readily 'forced' in autumn; and thus in late November and December the flowers most readily available in shops are *Narcissus papyraceus* and *Viola odorata*.

Aquatics present a special case, since these do not at first sight appear to suffer at any time from lack of water: but in no station can permanence of fresh water be guaranteed indefinitely. In addition to risks of extreme drought, sub-aqueous environment is subject to other causes of failure, more particularly owing to rapid diminution of light in levels below the surface,

[1] Urban optimists, noting Primroses flowering in their gardens in mild December, write to the daily Press that Spring is at hand, before the onset of Winter. By the first week of December the first leaves of *Ranunculus Ficaria* appear above ground, as also the tips of the shoots of Snowdrop and Winter Aconite, the leaves of *Scilla* push up, and many common weeds germinate freely, *Poa annua*, *Galium Aparine*, *Veronica hederaefolia*; in garden-ground even tropical annuals, as *Tropaeolum majus*, to be killed by later frosts.

and again to failure of the supply of free oxygen in standing water. Aquatics presenting special buds or perennating structures (turions[1] of *Potamogeton*, *Hydrocharis*, *Myriophyllum*, tubers of *Sagittaria*), form these bodies under conditions of unfavourable environment, quite as much as on the approach of winter; the failure of light-supply being the more emphasized as flood-water rises in rivers and ditches. All such perennation-structures are to be regarded as similarly the derivatives of older systems of perennation,[2] retained from a warmer climate, and are in no case new departures as the response to a northern winter. Such bud-formations and tubers are in all probability as much the vestigial inheritance from an original land-habit as are the storage rhizomes. All these aquatics are very susceptible to severe frost, and rhizomes endure at the bottom, below the ice-level of the winter flood (*Nymphaea*, *Nuphar*, *Villarsia*). In the case of free-floating forms (*Lemna*, *Azolla*) buds sink to the bottom as the over-water parts are destroyed by frost.

From such generalizations it may be concluded—

(1) There is no special morphological mechanism for perennation over winter cold in any indigenous plant.

(2) All apparent adaptations are the retention of an older hot-season perennation-mechanism, now more or less adjusted to the change of season.

(3) This last may involve a physiological adaptation, implying a time-factor, and also increased resistance to cold.

(4) Otherwise all herbaceous perennials, at the onset of winter, stop as they are, and merely remain stationary for a few months until light is renewed, and temperature is more definitely on the up-grade.

The first week of December, which is also the last week of the University Term, sees the final closing down of the 'Fall' season, and Winter does not begin officially until Dec. 21; though the ecological winter may be defined as the period during which the trees are bare. The days are at their shortest; it grows dark at 4.30 p.m., trees and hedges are swept clear of leaves, and there is little show of green in the latter beyond residual Brambles and trails of Ivy. The main crop of fallen leaves is reduced to withered, shrivelled, and decaying relics; much has been pulled beneath the surface by worms, and the ground-flora is again exposed. Minor animal life has also closed down,[3] though late strays may long persist in mild spells. Even if not 'resting' all growth appears to have ceased. Yet the first suggestions of the new season are evident. In gardens, green tips of *Crocus* leaves appear above the soil, as also *Narcissus* (sp.), *Leucojum*, *Anemone*. In woodland green *Scilla* leaves push up, and residual autumn flowers mingle with the casuals of spring before any definite winter-cold has set in.

[1] Arber (1920), Water Plants, p. 69.

[2] loc. cit., p. 222.

[3] Gnats swarm (Dec.), Toad (Nov. 11), Hedgehog (Nov. 15), the last Butterfly (*Vanessa Io*, Dec. 5). The dead season of the year for animal and insect-life is perhaps most clearly marked locally by the shepherd's calendar for the autumn and spring Stow Fairs (Oct. 24–April 24). In milder seasons slugs do much damage, though snails are hibernating, and gnats have been seen dancing, Dec. 25 (1924), following over three weeks of S. and SW. wind; max. shade temp. by day about 50° F. and by night minimum about 40° F.

XII. MID-WINTER

For autotrophic plant-life, deriving its initial source of energy directly and solely from the sun, deprivation of light ends everything, and reduced temperature only exaggerates the effect of diminishing light-supply. All plant-life slows down to a minimum; with a temperature chilled to the freezing-point, even Fungi and Bacteria of decay slow down and stop. All growth comes to an end, and perennation prevails in all branches of the plant-kingdom. On Dec. 21, the shortest day, the hours of possible daylight are only $7\frac{3}{4}$, and the sun attains an altitude of but 14°, 48′ above the horizon at noon. For six weeks (Dec., Jan.) the sun rises after 8 a.m., and for about a month (Dec.) it sets before 4 p.m. The daylight soon runs out in dull weather after 2 p.m., and under best conditions the available light is but that of a summer evening; a low sun is always in one's eyes, and even on a clear day one can almost look at it at noon. Such fine days are uncommon, and the working capacity of daylight is greatly reduced by cloud and fog.[1]

Hours registered as bright sunshine average a total of 42·8 for the whole month; or out of total time $\frac{1}{17}$, or less than 6%; an average of 1·38 hours per day marking the least sunny month of the year. Sunshine when available is of the feeblest; e. g. photographic tables give it as $\frac{1}{4}$ to $\frac{1}{6}$ the intensity of the summer sun. In actual light-intensity (candle-power) the discrepancy is less, so long as the surface concerned is at right angles to the sun's rays; but horizontally extended leaf-laminae get little advantage from a sun less than 15° above the horizon. It is difficult to separate the actual photosynthetic value from the effect of temperature, and the condition of plant-life is the best witness to its inefficiency. The mean maximum temperature is 44·51°, the mean minimum 35·25°; but in mild spells the temperature may rise over 55° in the middle of the day, even bearing comparison with chilly days in August.[2] Rainfall is not excessive, but in dark months, with short days and no sun, evaporation may practically cease for a week or more at a time; the air is subsaturated, the ground and residual vegetation wholly sodden, heavy soils incapable of cultivation, and clays trampled into deep mires.

By mid-December all leaves of deciduous trees that are to be shed are now stripped, and lie wet and blackened in decomposing and drifted heaps; any still left on trees (Oak, Privet) may persist until Spring, or be slowly drifted by drying winds. The last debris of leaves killed on the branches, being brought down by snow or storm, may be swept up in mid-January, when the first traces of the new foliage appear on Elder in sheltered stations. Mid-January is the most naked time of the year; even Brambles being stripped, and few new buds pushing. Bracken is wrecked and broken down; the grass of the pastures where ungrazed tends to bleach, but remains green where close-cropped, though affording scanty herbage. After frosts, in cold dry winters, the hedges appear black against the faded pastures,[3] though arable fields may be tinted green with the young corn. A few perennating rosettes and shoots of herbaceous plants persist conspicuously in woodland and hedge-bottoms (*Carduus*, *Ranunculus repens*, *Lamium*, *Urtica*, *Anthriscus sylvestris*, with trails of Ivy), but much vegetation is buried beneath a mantle of dead leaves. While all higher plant-life is at a standstill, in damp woodland Mosses and Lichens attain more conspicuous

[1] Cf. Radcliffe Records; Dec. 1920, 15 days recorded with no bright sunshine at all.

[2] Dec. 18, 1921, 56·5°: Dec. 28, 1921, 57°: Dec. 24, 1920, 55·4°: Dec. 31, 1920, 55·8°.

[3] On calcareous soils (Wytham) the whitened fluffy fruit-clusters of *Clematis Vitalba* now stand out conspicuously in hedges and woodland, and can be seen at great distances, lending significance to the country name of 'Old Man's Beard'.

differentiation ; and in a subsaturated atmosphere these vegetate as freely as algae out of the water, working with a minimum of light, which now bears comparison with that of the woodland shade of the rest of the year. Although these grow more actively and reproduce at a higher temperature in May, their vegetative growth continues for the most part over the darker months ; though again liable at any time to arrest owing to frost. A period of fully three months, or a quarter of the year from mid-November to mid-February, comes under this heading of *Mid-Winter,* as the dead time of the year.

In these dark days of December and January, for all practical purposes the flora vanishes; whether the weather be open, mild and sodden, or cold and the ground covered by a mantle of snow. Beyond the gaunt perennating trees of hedgerows, the more visible flora is represented by starved evergreens of gardens, belated cabbages and Brussel-sprouts of allotments, and the few flowering plants of greenhouses, maintained for aesthetic purposes (Chrysanthemums, Cyclamen, *Erica,* and forced Tulips),[1] these appearing as curiosities rather than individual entities, and, so far as decorative value is concerned, little better than their imitations in paper or wax. By an urban population no longer dependent for fuel on the disappearing woodlands, or for meat on local pastures, or even for wheat on diminishing arable land, plant-life is largely forgotten, to the extent that the recovery of the spring comes to appeal as a vaguely interesting natural phenomenon, rather than the all-essential factor in the possibilities of human existence in the district.

On dull days it gets dark at 4 o'clock in the afternoon, and even in the finest weather the sun is no higher at noon than it is in July summer at 5 p.m., when men stop working for the day ('summer time'). This increase in the hours of darkness, even more than reduced temperature, drives men indoors, and increases the attraction of town-life for half the year, so that the working plant is forgotten. An urban servile population, cut off from their relation to the land on which they live, buying food in shops without thinking about where it comes from, represents the natural consequences of modern commercialism and industrialism,—wholly opposed to all primary relations of man to the plant, and the plant to the land,—eminently artificial, and hence of no prolonged duration. It may last some time yet, even in generations; but it cannot go on indefinitely, since it has no bearing on the biological evolution of an up-grade race.

To early inhabitants of this country, the coming of the dark days meant Mid-winter, more than mere low temperature, frost, snow, and mud. Mid-winter thus coincided with the winter-solstice: January was known by the suggestive name of Wolf Month to the Saxons. Human life in the cold and wet woodland, however pleasant it may appear in summer, becomes impossible without a fire; a fire impossible without protection from wind and rain. In the absence of caves this led to the local utilization of Hazel of the underwood, and Willow of the swamp-forest for wattle-huts, to which the tenacious clays supplied the daub. Roofing was afforded by reed-thatch or turves. That is to say, the first human problem in permanently occupying the district was that of *perennation,* on much the same footing as the plants. Early man struggled primarily against the winter climate, as undoubtedly did also the vestigial larger immigrant mammals. Many of these are known to have died and left their bones (as at the Cherwell gravel-bank, Magdalen Grove),[2] but it does not follow that they lived over the winter. Only when fuel, clothing, and huts were effective, could man be said to dominate the land by increasing the summer-growths for crops and cattle. Hence the agriculturalist period followed that of the squalid and nomadic hunter in this part of the world, without at all implying that this was the normal or main story of human

[1] Imported *Viola odorata, Mimosa dealbata, Narcissus papyracea, N. Tazetta* ('Soleil d'or').
[2] Gunther (1923), *Ursus anglicus,* Ann. Mag. Nat. Hist., vol. xi, p. 490.

progression on the world in general. With advancing civilization the Oak became the ideal timber of building-construction, and straw of the alien Wheat was utilized for thatch. In Saxon times the Oak was considered too important to fell for timber, as it was an essential food-tree for hogs,[1] and woodland was valued according to the number of hogs it would feed. Stringent laws, in fact, were made against felling the Oak. Thus Bagley Wood may have grown good Oaks in past time, yielding a bushel of acorns or more to a good tree, however scanty the yield at the present time, when no large trees are left standing. The fact that Abingdon Abbey, in the thirteenth century[2] sent ox-teams throughout a summer to fetch oak-timber from N. Wales, indicates not so much the inferiority of Bagley timber, as their disinclination to fell good trees. This also throws light on the popularity and abundance of hedgerow Elm, which gives nothing but its timber, and is readily worked when wet; the tree also regenerates freely from suckers without special care. In the absence of wolves, the rabbit becomes a recognized pest of modern enclosed woodland.

The closing down of the University for the winter vacation also follows the darkest days, from times when fuel was scanty, libraries were not allowed to have fires, and candles afforded a feeble artificial light. The fur-lined hood of Bachelors is still suggestive of times when it was a necessity of student life. From the last century timber-fuel is replaced by coal, Oak for building by cheap imported Pine; lath and plaster replaced wattle and daub, though both are now looked at askance by building authorities. Both Oxford and Kimeridge Clays are burnt for bricks; and since the expansion of the town area following the coming of the Railway, Oxford has become mainly brick in construction. In all these respects the former dependence of man on the local flora for bare existence over the winter-period tends to become forgotten, as a population which has outgrown its local food-supply must also outgrow the possibilities of its timber-output and woodland industries.

A few flowers may persist as casuals and residual strays, as starved specimens in sheltered spots, particularly near habitations, thus humanly assisted and largely alien weeds. These relics and vestigia of the past season are of little use to the plant, and such depauperated individuals serve to emphasize the wreckage of the flora. With these relics of the vanished summer mingle a few precocious forms anticipating the spring recovery: among these may be included—

Plants of sheltered woodland, imperfectly perennating, and hastened by mild weather—

Primula vulgaris, *Viola Riviniana*, *Corylus Avellana*,
Mercurialis perennis, *Ulex europaeus*.

Pasture-plants continuing autumnal habit—

Bellis perennis, *Taraxacum officinale*, *Achillea Millefolium*.

Weeds of Roadsides and Hedge-bottoms—

Hordeum murinum, *Poa annua*, *Lamium album*,
Geranium Robertianum, *Anthriscus sylvestris*, *Arrhenatherum avenaceum*.

Plants of sheltered walls—

Linaria Cymbalaria, *Senecio squalidus*, *Hieracium murorum*,
Arenaria serpyllifolia.

Weeds of Cultivated Land—

Lamium purpureum, *Stellaria media*, *Veronica Tournefortii*,
Capsella Bursa-pastoris, *Senecio vulgaris*, *Ranunculus repens*,
Euphorbia Helioscopia, *Euphorbia Peplus*, *Poa annua*.

Garden-flowers in cultivation in the open—

Viburnum Tinus, *Jasminum nudiflorum*, *Helleborus niger*,
Vinca major, *Galanthus Elwesii*, *Iris stylosa*,
Daphne Mezereum, *Daphne Laureola*, *Viola altaica*.

[1] Cox (1905), The Royal Forests of England, p. 68: cf. Laws of Canute and Ina of Wessex.
[2] Jeudwine (1912), The First Twelve Centuries of British Story, p. 319.

Early agricultural inhabitants of the country, equally immigrant with the plants from a warmer southern climate, celebrated the turning of the sun and the opening out of the hours of daylight with religious ceremonies (as more or less magical rites) symbolical of the renewal of life and the increase of crops and herds in the coming spring. Originally associated with the beginning of the New Year, now ten days after the winter solstice, these have been more generally transferred to Christmas, with only three days' grace. In a deteriorated northern forest-zone, away from the more evergreen woodland of SE. Europe, these customs linger on, and the best has to be made of the evergreen forms available. Locally even the types characteristic of the indigenous flora are at the lowest ebb; though maintained by tradition among a mixture of alien importations.

Pinus sylvestris does not now grow wild, and there is no record that it ever did, though fine trunks have been recovered from a peatbog at Sutton Park, distant 50 miles north.

Taxus is the only Conifer present, and this, being poisonous to cattle, has been relegated to churchyards (Iffley, Binsey) and cultivated ground, no longer a woodland form (planted in Bagley Wood).

The magic properties of the *Loranthus europaeus*, growing on the *Quercus Ilex* in SE. Europe, have been transferred to *Viscum album*, the Mistletoe; but even this does not grow wild, though spreading by the agency of roosting birds from the Botanic Garden for a few hundred yards.

At a time when the most brightly coloured berries of Autumn (*Viburnum Opulus*, *Rosa canina*, *Taxus*, *Euonymus europaeus*, *Pyrus Aucuparia* and Privet) have been taken by birds or largely spoilt by frost, the Holly with most unpalatable scarlet berries remains conspicuous. But even Holly is increasingly uncommon, except where planted, and secured from the depredations of Christmas exploiters.

The Ivy alone remains as the commonest evergreen, with its half-grown berries, abundant in neglected woodland, and retaining ancient associations, Bacchic rather than Christian.

In modern times such evergreens are eked out with Bay (*Laurus nobilis*), Cherry Laurel, Cupressus, Thuya, Spruce (for Christmas Trees) Box, *Cedrus*, *Viburnum Tinus*, *Rosmarinus*, and *Berberis Aquifolium*.

Though the close of the calendar is a wholly arbitrary, if necessary, convention, retained since it coincides very fairly with the closing down of the flora in North Temperate Latitudes, plant-life is still moving, even if too feebly to be perceptible, and new features begin before the old ones fade. So long as the earth goes round the sun, with its axis inclined at a very constant angle with the plane of the ecliptic, seed-time and harvest, cold and heat, summer and winter, day and night, cannot cease in this part of the globe; the main cycle of the annual succession of plant-life being the response to the astronomical organization of the solar system. Hence the story repeats in successive years with a precision which at once affords the most mysteriously beautiful feature of the countryside, as it is the most constant factor in determining the main lines of all social organization. In an age which exploits coal and petrol, it is well to remember that human life is still wholly dependent on living plant-plasma, and likely to remain so indefinitely. The world-supply of coal and petrol is, after all, finite, and the plant remains the simplest and cheapest means of obtaining current supplies of solar energy, as well as being the source of essential food-substances beyond the hopes of chemical synthesis.

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